

GULF RESEARCH REPORTS

Vol. 5, No. 1
December 1975



Published by the
GULF COAST RESEARCH LABORATORY
Ocean Springs, Mississippi

Gulf and Caribbean Research

Volume 5 | Issue 1

January 1975

Editorial

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DOI: 10.18785/grr.0501.01

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Recommended Citation

Howse, H. D. 1975. Editorial. *Gulf and Caribbean Research* 5 (1): i-i.
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Editorial

Gulf Research Reports was founded in 1961 by Dr. Gordon Gunter to fill an existing need of a new outlet for scientific information on the Gulf of Mexico and adjacent waters. But assuming the new chore as editor and developing the journal exacted the penalty of time from other scholarly endeavors, thus he brushed them aside to be dealt with another day. It is not without some degree of trepidation that I accept the editorial torch from Dr. Gunter. The compensating consolation is his willingness to continue to sacrifice some of his time as consulting editor, for which I am most grateful.

Dr. Gunter has received world-wide recognition for his numerous contributions to marine science, scientific writing and editing. His new freedom from various deadlines, after so many faithful years, will finally allow him time to address matters that were shelved for so long.

Changes in the economy have brought changes in the format of the *Reports*. The page size has been enlarged to accommodate more typescript per page, but more especially to provide for clearer and more easily read tabular and graphic material. But even so, it became necessary to impose a nominal page charge to help defray the cost of publication. Information for contributors has been prepared and published in this volume for the guidance of investigators desiring to publish their work in the *Reports*. To ensure high quality and relevance, the editorial policy is to publish only those manuscripts reviewed and found acceptable by at least two referees.

The *Reports* is now circulated to 675 subscribers throughout the nation and seventy-two foreign countries. Further steps will be taken with the objective of substantially increasing the service and circulation of the *Reports* to the scientific community.

HAROLD D. HOWSE

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Recommended Citation

Welker, B., S. Clark, C. Fontaine and R. Benton. 1975. A Comparison of Petersen Tags and Biological Stains Used With Internal Tags as Marks for Shrimp. *Gulf Research Reports* 5 (1): 1-5.
Retrieved from <http://aquila.usm.edu/gcr/vol5/iss1/2>

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A COMPARISON OF PETERSEN TAGS AND BIOLOGICAL STAINS USED WITH INTERNAL TAGS AS MARKS FOR SHRIMP¹

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ABSTRACT During May 20-31, 1968, 14,301 brown shrimp (*Penaeus aztecus*) were marked and released in Biloxi Bay, Mississippi. Of these 7,023 were marked by injection with a combination of Niagara Sky Blue 6B stain and polyvinyl chloride (PVC) internal tags and 7,278 were marked with Petersen tags. The objectives of this experiment were to compare the two methods as marks for shrimp and to obtain information on growth rates and migrations. Eighteen weeks after release, 1,942 (28%) of those marked with the biological stain-internal tag combination and 2,286 (31%) of those marked with Petersen tags had been recovered. The difference in proportions recaptured (significant at $P < 0.01$) could have resulted from greater ease in recognition of the Petersen tag by commercial fishermen or from differential marking mortality, although no evidence was found that differential marking mortality occurred. Marking mortality was observed for both marks and appeared inversely related to size at time of marking. No significant differences were found between growth rates of shrimp marked with the biological stain-internal tag combination and those of shrimp marked with the Petersen tag, although most weekly average increments for stained shrimp were higher. Rates of return were similar in the vicinity of the release area, although a significantly higher proportion ($P < 0.01$) of returns from waters outside of Biloxi Bay were marked with Petersen tags. Again, this was attributed primarily to greater ease in recognition by commercial fishermen. It was concluded that the Petersen tag was the more effective of the two marks as it appeared to be recognized more readily over longer periods of time than the biological stain.

INTRODUCTION

Development of yield models for penaeid shrimp fisheries of the Gulf of Mexico requires reliable estimates of rates of growth and mortality. Mark-recapture studies are useful in obtaining such information, and several have been conducted on penaeid shrimp in the Gulf of Mexico; a review of the marks and marking procedures used is to be found in Neal (1969).

The Petersen tag was used in such studies from 1935 through 1947 by Lindner and Anderson (1956), and later by McRae (1952), Iversen and Idyll (1960), Iversen and Jones (1961), Iversen (1962) and Klima (1964). In these studies, marking mortality in smaller shrimp was often higher than in larger shrimp; Iversen and Jones (1961) also noted that swimming was impaired. These problems led to experiments to devise more suitable marks, and as early as 1955 Menzel (1955) successfully marked white shrimp (*Penaeus setiferus*) by injection with a solution of Fast Green² biological stain. Dawson (1957) experimented with several biological stains and found that injected solutions of Fast Green FCF (National Aniline), Niagara Sky Blue 6B, Trypan Red, and Trypan Blue provided marks which lasted over 100 days. Subsequent field and laboratory tests (Costello 1959; Costello and Allen 1962) verified the effectiveness of biological stains as marks for shrimp, and the stain-injection method was later used in a series of mark-recapture experiments in

the Gulf area (Klima 1964; Allen and Costello 1966; Knight and Berry 1967; Klima 1974).

Utility of the stain-injection technique was limited because only groups of shrimp and not individuals could be identified. This led to use of fluorescent pigments (Klima 1965) to identify different classes and small PVC internal tags (Neal 1969) to identify individuals. These tags could be inserted into the musculature directly under the exoskeleton, whereas the pins holding the Petersen tags had to be thrust completely through the abdomen. Therefore, the stain-internal tag combination showed promise in reducing the trauma of marking and in avoiding impairment of swimming and burrowing that might be expected from use of the Petersen tags.

The objectives of this study were (1) to compare recapture rates of shrimp marked with the biological stain-internal tag combination and with Petersen tags, and (2) to obtain information on growth rates and migrations.

MATERIALS AND METHODS

The study was conducted in Biloxi Bay, Mississippi (Figure 1), which supports an intensive bait shrimp fishery and also contributes to the food shrimp fishery in Mississippi Sound and adjacent offshore waters. A portion of the Bay is closed to shrimping (Figure 1); the remainder is subjected to heavy fishing pressure.

To obtain cooperation of local fishermen, news releases were published and posters were distributed. These described the types of marks used and offered a reward for the return of marked shrimp together with the date and location of capture. Returns were handled by National Marine Fisheries Service personnel in cooperation with shrimp dealers who

¹Contribution No. 386, National Marine Fisheries Service Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Texas 77550.

²The use of trade names in this publication does not imply endorsement of commercial products.

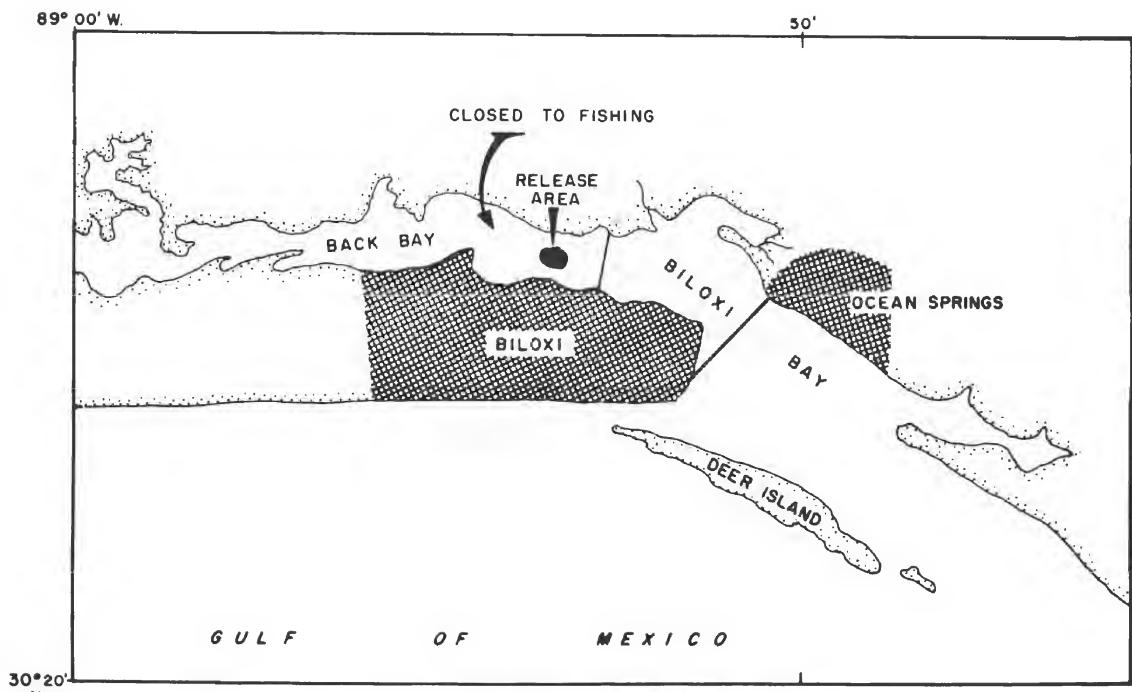


Figure 1. Biloxi Bay, Mississippi and location of the release area.

were provided fixative to preserve marked shrimp and forms for recording data.

Brown shrimp (*Penaeus aztecus*) to be marked were caught in the Bay with a 4.6-m otter trawl and were held in a closed recirculating system of the type described by Emiliani (1971). These shrimp were divided into two groups; the first group was marked with Niagara Sky Blue 6B stain and internal tags, while the second group was marked with Petersen tags. Each shrimp marked with the former combination was injected first with 0.12 ml of a 0.125-percent solution of Niagara Sky Blue 6B stain in distilled water (Neal 1969); a numbered PVC tag approximately 5 mm long, 2 mm wide and 0.25 mm thick was then dipped in a 10% mixture of the antibiotic Aureomycin in white petroleum jelly (Benton, personal communication) and inserted with forceps into the abdominal musculature behind the carapace. The combination was used to mark 7,023 shrimp.

A modified Petersen tag (Benton, personal communication) was used to mark the second group of 7,278 shrimp. The tag consisted of two green PVC disks (one numbered and coded and one blank) approximately 6 mm in diameter and 0.5 mm thick attached to the shrimp with a stainless steel pin. In tagging, the numbered disk was placed on the pin, then the pin was dipped in the antibiotic mixture and inserted through the articular membrane between the first and second abdominal segments. The blank disk was slipped onto the protruding end of the pin, which was cut and

crimped to secure the tag. A 6-mm excess length of pin was left to accommodate growth.

After each shrimp was marked, its total length (tip of rostrum to tip of telson) was measured to the nearest mm. Groups of marked shrimp then were released below the surface through a release tube described by Emiliani (1971). Because all marked shrimp were released within the area closed to fishing (Figure 1), they initially received some protection. As they moved out through the bay and into adjacent offshore areas, however, they were subjected to heavy fishing pressure.

RESULTS AND DISCUSSION

A total of 1,942 (28%) shrimp marked with Niagara Sky Blue 6B stain and internal tags and 2,286 (31%) shrimp marked with the Petersen tags were recovered. The difference between these proportions was significant (chi-square = 24.1 with 1 degree of freedom, $P < 0.01$). Recapture rates for both marked populations were high initially but declined rapidly as the experiment progressed (Figure 2). We attributed this pattern to migration and to the distribution of fishing effort. The shrimp were marked as large juveniles immediately prior to offshore migration and had to pass through a heavily fished channel where the opportunity for capture was much higher than in adjacent offshore waters. Thus, the bulk of the recoveries were made within a relatively

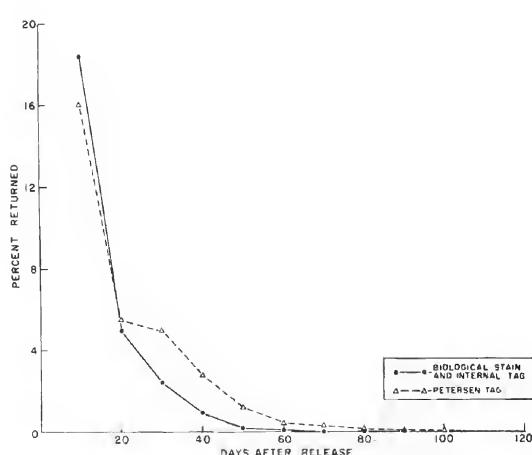


Figure 2. Relationship between percent returns and time for brown shrimp marked with Niagara Sky Blue 6B stain and internal tags and brown shrimp marked with Petersen tags, Biloxi bay and vicinity, 1968 (plotted points represent percentages recaptured during the preceding 10-day time interval).

short time. Percentage returns were consistently higher for the Petersen tag after the first 20 days of the experiment (Figure 2).

The reasons for the observed difference in the proportions returned are uncertain, but we judged two factors to be of importance. First, marking mortality would be expected from either procedure, and accordingly we felt that differential marking mortality could have biased return rates. To evaluate this possibility, we plotted percent returns for each mark type by 5-mm size class (at time of release). No consistent trends were observed (Figure 3). Thus, there is no evidence that differential marking mortality occurred in this study, although marking mortality is evident for both marking methods in the smaller size classes studied. It is also possible that the two marking procedures could have had a differential effect on catch rates although the extent to which this may have occurred is impossible to determine.

Another possible explanation for the higher proportion of Petersen tag returns, and one which appears more tenable, is that this mark would be much more easily recognized than biological stain by commercial fishermen because the stain becomes localized and fades. Immediately after injection with Niagara Sky Blue 6B stain, shrimp retain a distinctive blue color in the abdominal region for a brief period, and if released immediately (as was the case in our study) they can be easily recognized. Within a few days, however, the stain concentrates in the branchiae and is much less easily recognized. Thereafter, this stain remains fast for at least 5 or 6 months (Neal 1969), although it fades to varying degrees depending on volume and concentration administered, growth of the shrimp, and other variables (Emiliani, personal communication). In contrast, the Petersen tag can be recognized with ease regardless of elapsed time. We

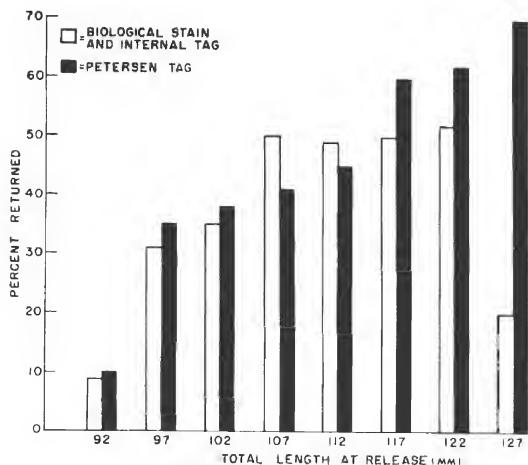


Figure 3. Relationship between percentage recaptured and size at release of brown shrimp, Biloxi Bay, Mississippi, 1968 (each length presents the midpoint of the corresponding 5-mm total length group).

believe that this factor was primarily responsible for the observed difference in rates of return between the two marking methods.

The possibility for differential effects of the two marking methods on growth and movement remains to be considered. To evaluate the relative influence of the Niagara Sky Blue 6B stain-internal tag combination and the Petersen tag on growth, we again combined recovery data by 5-mm size classes at time of release and calculated mean increments in total length for 10-day time intervals between release and recovery. We then conducted paired t-tests for each 5-mm size class to compare growth rates between the two marked populations. Time intervals were not included unless the number of recoveries for each mark type exceeded ten. Results of these tests are given in Table 1.

TABLE 1.

Results of paired t-test comparisons of mean increment in total length of brown shrimp marked with the Niagara Sky Blue stain and internal tag combination and Petersen tags, Biloxi Bay, Mississippi, May 1968. Recovery data for each mark were sorted by size at time of release and by 10-day intervals between release and recovery; observations consisted of mean increment in millimeters attained in each interval.

Size at Release (Total Length in mm)	Value of t	Degrees of Freedom ¹
090-094	1.30	3
095-099	1.73	3
100-104	1.90	3
105-109	0.09	3
110-114	-8.40	1
115-119	0.38	1

¹ One less than the number of 10-day time intervals used.

None of the observed differences were significant ($P > 0.05$). Thus, no evidence was found that the two methods had a differential effect on growth. It appeared, however, that both procedures had an initial effect on growth; throughout the range of size classes studied, growth rates for both marked populations were considerably lower during the first 10 days after marking than later in the experiment (Figure 4), apparently the result of stress and trauma (Fontaine and Dyjak 1973; Fontaine and Lightner 1973). Growth rates for both populations were quite similar during the first 10 days, but as the experiment progressed, shrimp marked with the stain-internal tag combination grew faster than did shrimp marked with the Petersen tag (Figure 4). This suggests that growth rates determined from returns of shrimp marked by the former procedure may be more accurate.

We evaluated the relative effects of the two marking procedures on local migrations by referencing recoveries to a prearranged grid system (Figure 5). We then compared proportions of each marked population recaptured in the immediate vicinity of the release area and in the surrounding

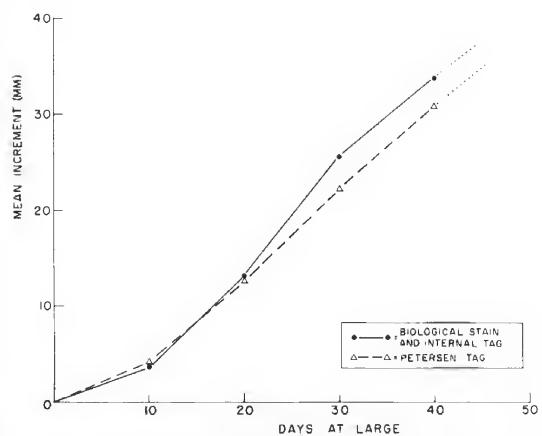


Figure 4. Growth of brown shrimp (size classes combined) marked with Niagara Sky Blue 6B stain and internal tags and Petersen tags, Biloxi Bay, Mississippi.

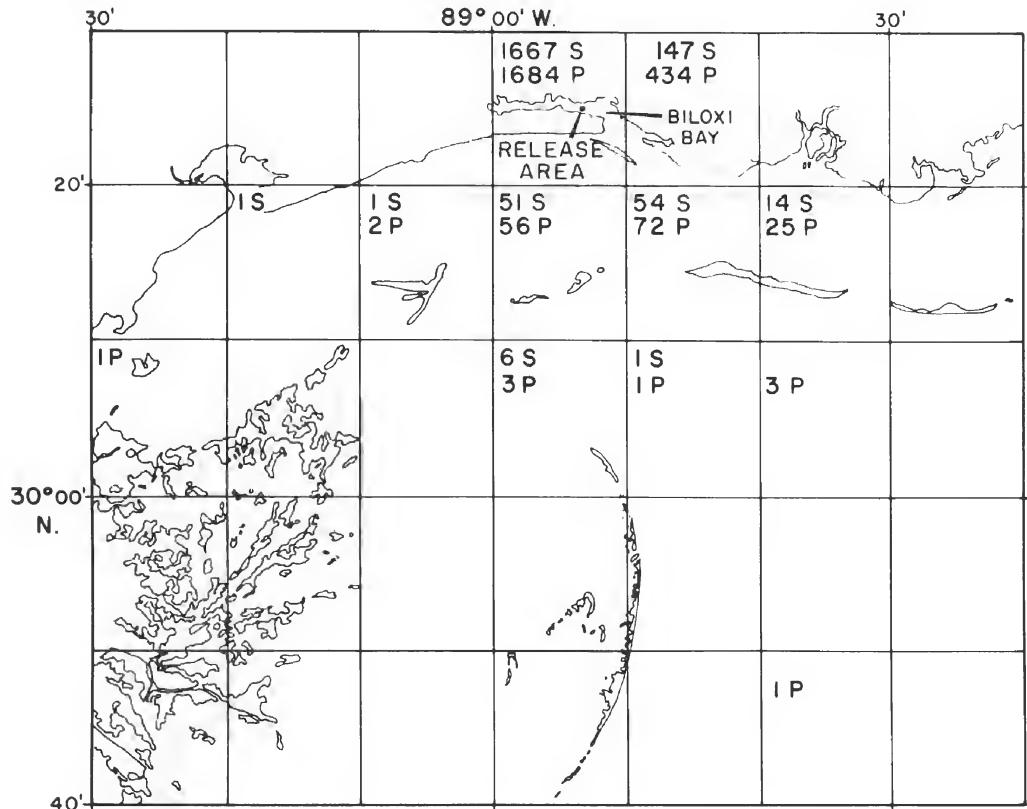


Figure 5. Distribution of brown shrimp recoveries by area, Biloxi Bay and vicinity, 1968. "S" refers to stain-internal tag combination; "P" refers to Petersen tag. (Note that area of recovery was not reported for four Petersen tag returns.)

areas. No significant differences in recovery rates between the two marking methods were found near the release area (chi-square = 0.41 with 1 degree of freedom, $P > 0.05$), but a significantly greater proportion of shrimp tagged with Petersen tags was recovered in the surrounding area (chi-square = 103.6 with 1 degree of freedom, $P < 0.01$). As the time factor is again involved, however, it appears likely that these results may have been biased by localization and fading of the biological stain. For this reason the relative effect of these methods on migration remains undetermined.

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Gulf Research Reports

Volume 5 | Issue 1

January 1975

Mississippi Flora. IV. Dicotyledon Families With Aquatic or Wetland Species

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DOI: 10.18785/grr.0501.03

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MISSISSIPPI FLORA. IV. DICOTYLEDON FAMILIES WITH AQUATIC OR WETLAND SPECIES

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ABSTRACT Keys, distribution maps, habitats, references, nomenclature, and notes are given for some 12 families of dicotyledons occurring naturally or naturalized in Mississippi. These families contain one or more species which are found in aquatic or wetland habitats. They are: Bataceae, Callitrichaceae, Ceratophyllaceae, Elatinaceae, Haloragaceae, Hydrophyllaceae, Lentibulariaceae, Lythraceae, Nymphaeaceae, Podostemaceae, Polygonaceae, and Saururaceae.

INTRODUCTION

The first paper in this series treated some of the monocotyledon families with aquatic or wetland species (Jones 1974). The primary aim of this paper is to improve our knowledge of some of the dicotyledon families with aquatic and wetland plants in Mississippi. Hopefully, this paper will be reviewed and criticized by many, and corrected before the proposed Guide to the Flora of Mississippi is published. Any overlooked species, additional collections, needed modifications, or suggestions should be sent to me as soon as possible so that corrections can be made.

In undertaking any floristic work one must use information previously published. Included here are the various manuals that cover some of the species that are found in Mississippi: Small (1933), cited as S in the synonymy; Fernald (1950), cited as F; Gleason and Cronquist (1963) cited as G; Radford, Ahles, and Bell (1968), cited as R. Other frequently used manuals included Steyermark (1963) and Correll and Johnston (1970). Noteworthy is the illustrated manual of aquatic and wetland plants by Correll and Correll (1972) which I highly recommend. Many taxonomic revisions were also used in the preparation of the present paper and they are cited in the text.

The keys to the genera and species not only include the

plants of our area, but in many instances have been written to include plants that might eventually be found in Mississippi. Unless otherwise noted, I have examined one or more specimens of each species from the state. Specimens were examined at the following herbaria: University of Mississippi, Mississippi State University, and the University of Georgia. The taxonomic format follows that of the contributors guide to the Mississippi Flora project. The abbreviation of authors' names in this paper follows that of Correll and Johnston (1970). It should be noted that some species are included which do not grow in aquatic or wetland habitats. This was necessary in order to test the keys within the families for the proposed guide. Family keys were not included since all dicotyledon families are not covered in this paper. I would suggest to the reader the family keys in Correll and Johnston (1970), Correll and Correll (1972), or Gleason and Cronquist (1963).

The physiographic regions of Mississippi, based upon Lowe (1921), are outlined in Figure 1. The abbreviations used in the text are: 1) Tennessee River Hills, TRH; 2) Northeastern Prairie Belt, NPB; 3) Pontotoc Ridge, PR; 4) Flatwoods, FW; 5) North Central Plateau, NCP; 6) Jackson Prairie, JP; 7) Loess Bluff Hills, LBH; 8) Yazoo-Mississippi Delta, YMD; 9) Longleaf Pine Region, LPR; 10) Coastal Pine Meadows, CPM.

BATACEAE

1. BATIS L.

1. *B. maritima* L., June-Aug. Brackish marshes, salt flats, mud flats; common along the coastal strands. Fig. 1.

CALLITRICHACEAE

1. CALLITRICHE L. WATER STARWORT, WATER CHICKWEED

1. Fruit as long as wide or a little longer, rarely slightly wider than long; stigmas 0.7 mm or more long; anthers 0.3-1.5 mm wide; plant amphibious	1. <i>C. heterophylla</i> .
1. Fruit broader than long by at least 0.2 mm; stigmas 0.2-0.4 mm long; anthers 0.1-0.2 mm wide; plants mostly terrestrial or on mud.	
2. Fruit 0.3-0.8 mm wide, gibbous at base	2. <i>C. peploides</i> .
2. Fruit 0.5-1.2 mm wide, not gibbous at base	

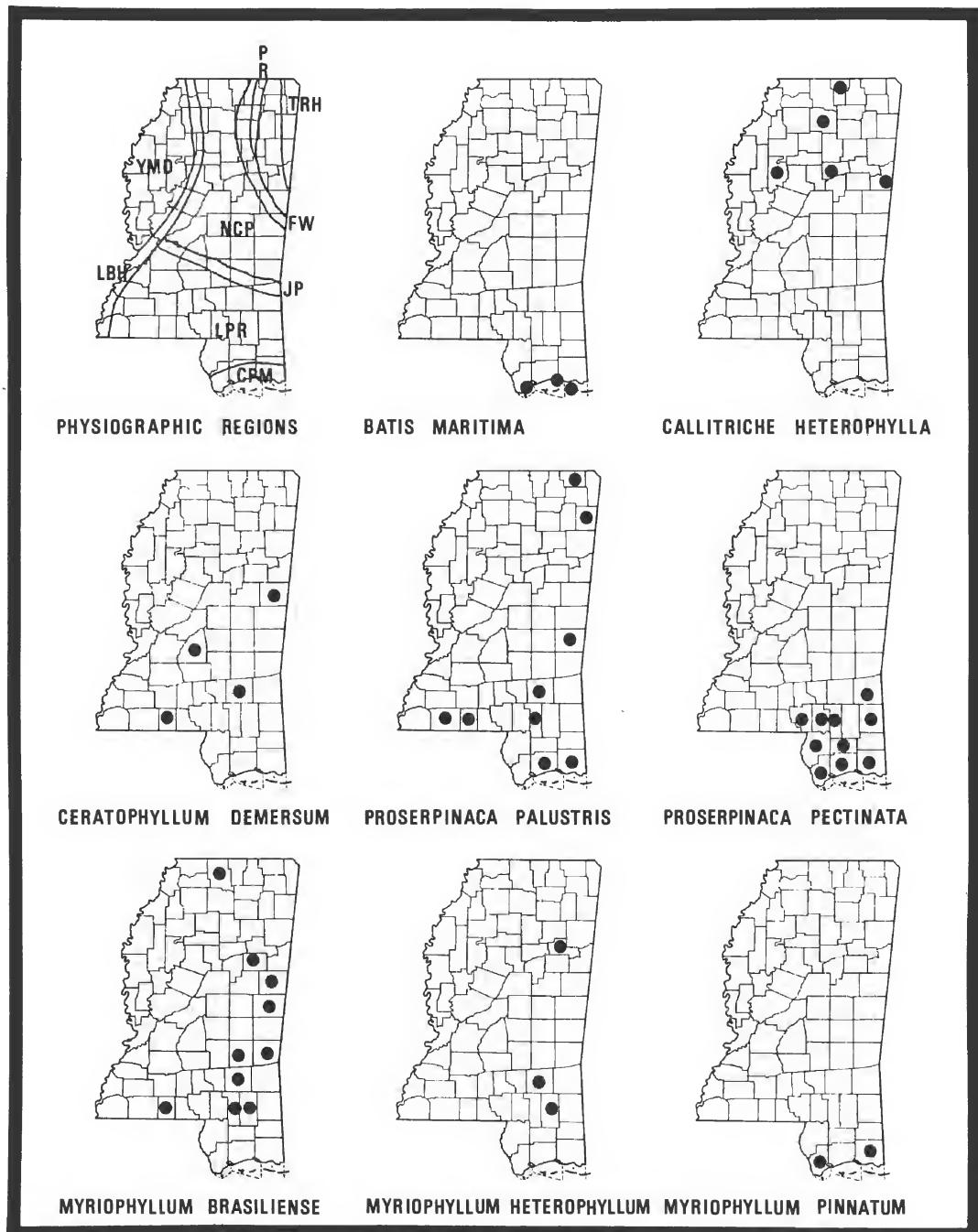


Figure 1. Physiographic regions (see explanation in text) and distribution in Mississippi of *Batis maritima*, *Callitricha heterophylla*, *Ceratophyllum demersum*, *Proserpinaca palustris*, *Proserpinaca pectinata*, *Myriophyllum brasiliense*, *Myriophyllum heterophyllum*, and *Myriophyllum pinnatum*.

3. Fruit pedicelled; wing and thin margin of carpel turned outward at right angles to the surface of the fruit or revolute and appearing like a thickened margin.

3. Fruit almost sessile; margin of carpel appearing as if not winged but under high magnification showing a minute wing

1. *C. heterophylla* Pursh *emend.* Darby, Mar.—Oct. Shallow water of ponds, sluggish streams, wet ditches; NCP, NPB, YMD, Fig. 1.

2. *C. peploides* Nutt., Mar.—Oct. Muddy or sandy wet ditches; Pearl River Co.

3. *C. nuttallii* Torr., Mar.—May. Damp soil, fallow fields, flats; Harrison Co.

4. *C. terrestris* Raf. *emend.* Torr., Mar.—June. Damp soil, moist lawns, open disturbed habitats; YMD, LPR, Sharkey and Lamar Counties. *C. deflexa* A. Br.—R, G; *C. deflexa* var. *austini* (Engelm.) Hegelm.—F. Plants of the last three species are easily overlooked and are probably more common than our records indicate. The treatment of *Callitricha* was adapted in part from that of Fassett (1951).

CERATOPHYLLACEAE

1. CERATOPHYLLUM L. HORNWORT, COONTAIL

1. Leaf segments conspicuously serrate on one side, leaves usually forked only 1 or 2 times

1. Leaf segments entire or nearly so, leaves usually forked 2 to 4 times

1. *C. demersum* L., June—Aug. Quiet water of lakes, ponds, slow streams; LPR, NPB; in southern Mississippi. Fig. 1.

2. *C. echinatum* Gray, June—Aug. Quiet water of streams, lakes; reported by R to be in Mississippi but no specimens have been seen.

ELATINACEAE

1. ELATINE L. WATERWORT

1. *E. triandra* Schkuhr, May—June. Shallow water of lake shore; NCP, Clarke Co. *E. americana* (Pursh) Arn.—F.

E. triandra var. *americana* (Pursh) Fassett—G. Useful references on *Elatine* include Fassett (1939) and Duncan (1964).

HALORAGACEAE R. Br.

1. Leaves alternate; flower parts in threes

1. Leaves whorled; flower parts in fours.

1. PROSERPINACA L. MERMAID-WEED

1. Upper leaves lanceolate and serrate, submersed leaves pinnately divided.

1. All leaves pinnately divided

1. *P. palustris* L., May—Oct. Shallow water of swamps, ponds, about springs, along streams, in ditches; TRH, LPR, CPM. *P. amblygona* (Fern.) Small; *P. platycarpa* Small—S; *P. palustris* var. *amblygona* Fern.—F. Fig. 1.

2. *P. pectinata* Lam., Apr.—Aug. Acid, peaty soils of swamps and savannahs, in shallow water of bay heads, ditches; LPR, CPM. Fig. 1.

2. MYRIOPHYLLUM L. WATER-MILFOIL

1. Leaves pectinate, feather-like, mostly emersed

1. Emersed leaves not pectinate, most leaves submersed.

2. Submersed leaves with 5 to 10 capillary divisions on each side; seeds with smooth ridges

2. Submersed leaves with about 5 capillary divisions on each side; seeds with 2 prominently tuberculate ridges

1. *M. brasiliense*.

2. *M. heterophyllum*.

3. *M. pinnatum*.

1. *M. brasiliense* Camb., PARROT'S FEATHER, WATER FEATHER. Mar.–Nov. Ponds, ditches, streams, moist soil; scattered throughout; native of South America escaping from cultivation and becoming persistent. *M. proserpinacoides* Gil.—S. Fig. 1.
2. *M. heterophyllum* Michx., Apr.–Aug. Ponds, lakes, streams; NPB, LPR. Fig. 1.
3. *M. pinnatum* (Walt.) B.S.P., Apr.–Oct. Swamps, ponds, streams; CPM. Fig. 1.

HYDROPHYLACEAE

1. Leaves entire; ovary two-celled; plants aquatic	3. <i>Hydrolea</i> .
1. Leaves toothed or compound; ovary one-celled; plants not true aquatics.	
2. Flowers solitary in leaf axils	1. <i>Nemophila</i> .
2. Flowers several to many in a cyme	2. <i>Phacelia</i> .

1. NEMOPHILA Nutt. BABY BLUE EYES

1. *N. microcalyx* (Nutt.) Fisch. & Mey., Mar.–Apr. Moist rich woods; LBH. Fig. 2. The distribution of *Nemophila microcalyx* is shown in Constance (1941).

2. PHACELIA Juss. SCORPION WEED

1. *P. dubia* (L.) Trel., Apr.–May. Roadsides, fields; NPB.

3. HYDROLEA L.

1. Leaves ovate; calyx shorter than the corolla	1. <i>H. ovata</i> .
1. Leaves lanceolate; calyx equal to the corolla in length.	
2. Calyx glabrous or very minutely and inconspicuously puberulent	2. <i>H. uniflora</i> .
2. Calyx sparsely hirsute with spreading hairs	3. <i>H. quadrivalvis</i> .
1. <i>H. ovata</i> Choisy, July–Sept. Roadside ditches, margins of ponds, moist soil along rivers; NCP, CPM. <i>Nama ovatum</i> (Nutt.) Britt.—S. Fig. 2.	
2. <i>H. uniflora</i> Raf., July–Aug. Low roadsides, moist soil along lakes, rivers, in shallow water of ponds; NCP, LBH, LPR. <i>Nama affinis</i> Gray—S. Fig. 2.	
3. <i>H. quadrivalvis</i> Walt., July–Oct. Wet soil; LPR, Forrest County. <i>Nama quadrivalve</i> (Walt.) O. Ktze.—S. A comprehensive reference for this family is Wilson (1960).	

LENTIBULARIACEAE

1. Rosette of leaves not present, leaves inconspicuous; calyx 2-lobed	1. <i>Utricularia</i> .
1. Rosette of conspicuous leaves present; calyx 5-lobed	2. <i>Pinguicula</i> .

1. UTRICULARIA L. BLADDERWORT

1. Plants usually terrestrial; leaves minute, inconspicuous; bladders minute or none.
2. Bracts at base of pedicels peltate, bractlets absent; pedicels filiform much longer than the bracts
2. Bracts at base of pedicels not peltate, minute bractlets present; pedicels stout, usually not longer than the bracts.
 3. Flowers crowded together at the very tip of the scape
 3. Flowers not crowded, separated along the scape
1. Plants aquatic; leaves conspicuous; bladders present.
 4. Corollas purple to rose-purple
 4. Corollas yellow.
 5. Petioles inflated forming a ring of floats at the base of the scape
 5. Petioles not inflated.
 6. Lower corolla lip 5–7 mm long, distinctly exceeding the thick, blunt spur
 6. Lower corolla lip 8–10 mm long, about equaling or slightly shorter than the conic spur

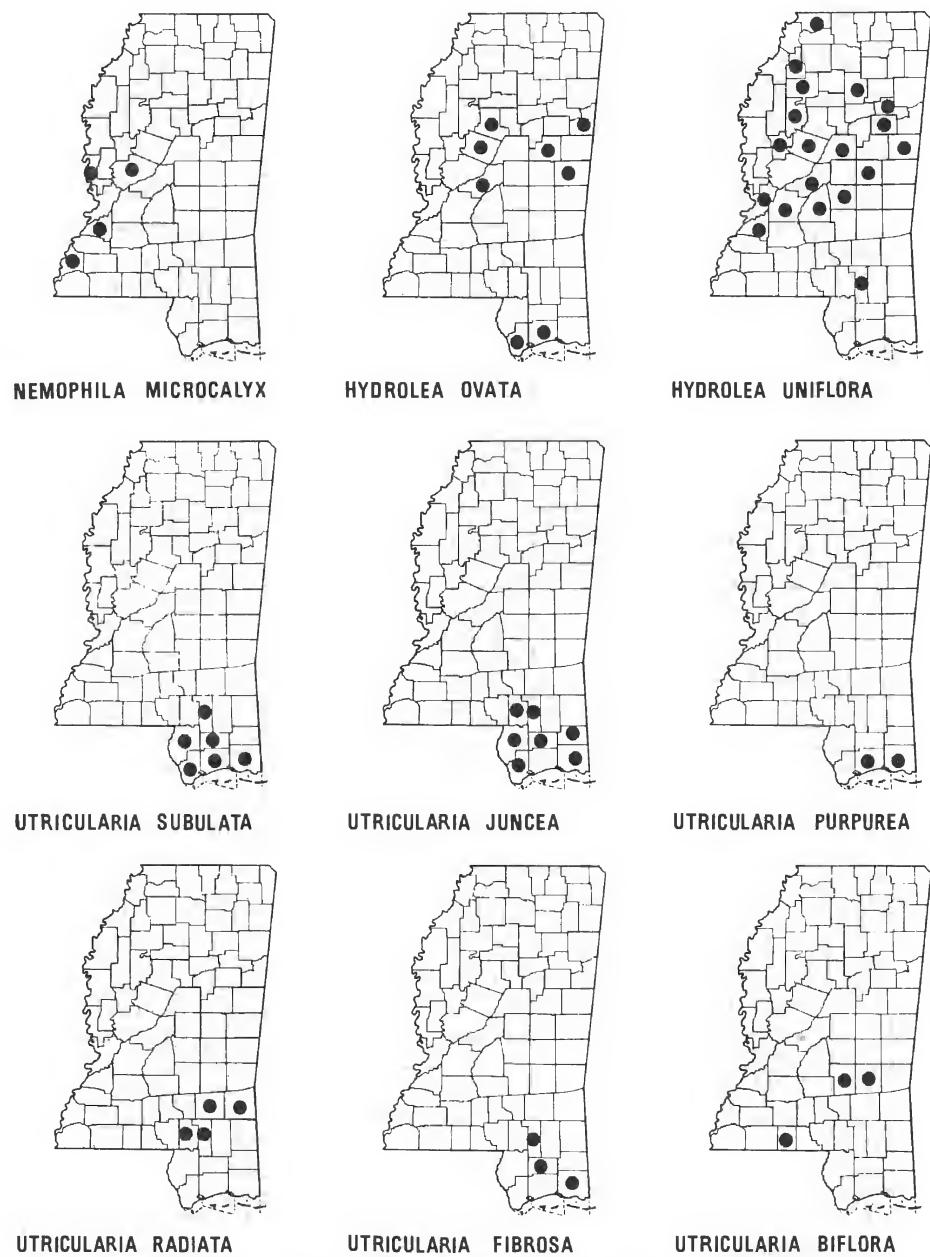


Figure 2. Distribution in Mississippi of *Nemophila microcalyx*, *Hydrolea ovata*, *Hydrolea uniflora*, *Utricularia subulata*, *Utricularia juncea*, *Utricularia purpurea*, *Utricularia radiata*, *Utricularia fibrosa*, and *Utricularia biflora*.

7. Leafy branches from the base of the flower stalk dimorphic, some with
and some without bladders 7. *U. fibrosa*.
7. Leafy branches all bearing numerous bladders 8. *U. biflora*.

1. *U. subulata* L., Mar.–May. Wet acid soil of bogs, pine flatwoods, bayheads, grassy savannas; LPR, CPM. *Setiscapella subulata* (L.) Barnh., *S. cleistigama* (Gray) Barnh.—S. Fig. 2.

2. *U. cornuta* Michx., HORNERED BLADDERWORT. July–Sept. Wet acid soil of bogs, moist pinelands; LPR, Forrest Co. *Stomoisia cornuta* (Michx.) Raf.—S.

3. *U. juncea* Vahl., July–Sept. Sandy soil of bogs, ditches, depressions; LPR, CPM. *Stomoisia juncea* (Vahl.) Barnh., *S. virgatula* Barnh.—S. Fig. 2.

4. *U. purpurea* Walt., PURPLE BLADDERWORT. Apr.–July. Submerged in water of shallow depressions, ponds, ditches; CPM. *Vesiculina purpurea* (Walt.) Raf.—S. Fig. 2.

5. *U. radiata* Small, FLOATING BLADDERWORT. Apr.–Sept. Floating on oxbow lakes, depressions, ditches; LPR. *U. inflata* Walt. var. *minor* (L.) Chapm.—R, F. Fig. 2.

6. *U. gibba* L., Apr.–Sept. Mud of marshes, margins of lakes, pools; YMD, NCP, Quitman and Madison Counties.

7. *U. fibrosa* Walt., Apr.–Sept. Shallow water of swamps, ponds; LPR, CPM. Fig. 2

8. *U. biflora* Lam., May–Sept. Shallow ponds, swamps; LPR. *U. pumila* Walt.—S. Fig. 2.

The key was adapted from the treatment by Correll and Correll (1972). Useful references on *Utricularia* include Reinert and Godfrey (1962) and Kondo (1972). The available specimens of *Utricularia* are of poor quality; additional collections are badly needed.

2. PINGUICULA L. BUTTERWORT

1. Expanded corolla not, or rarely, exceeding 1.5 cm across; rosettes rarely exceeding
3 cm in width 1. *P. pumila*.

1. Expanded corolla 1.8 cm or more across; rosettes 5 cm or more in width.

2. Flowers sulphur to golden yellow 2. *P. lutea*.

2. Flowers violet to whitish.

3. Leaves dull red or reddish-green; lobes of the corolla deeply incised 3. *P. planifolia*.

3. Leaves bright to yellowish green; lobes of the corolla merely notched 4. *P. primuliflora*.

1. *P. pumila* Michx., Mar.–May. Moist, acid, sandy soil of pine flatwoods, savannas; se LPR, CPM. Fig. 3.

2. *P. lutea* Walt., Mar.–May. Moist to wet sandy-peaty soils of bogs, pine flatwoods, savannas; se LPR, CPM. Fig. 3.

3. *P. planifolia* Chapm., Mar.–May. Shallow water at margins of depressions in flatwoods, ditches; se LPR, CPM. Fig. 3.

4. *P. primuliflora* Wood & Godfrey, Mar.–May. Shallow water of seepage areas, along streams, ditches, often in shade; se LPR, CPM. Fig. 3.

This treatment was adapted from that of Godfrey and Stripling (1961) and Wood and Godfrey (1957).

LYTHRACEAE

1. Large terrestrial shrub or small tree. 1. *Lagerstroemia*.

1. Herbs or aquatic suffrutescent shrub.

2. Aquatic suffrutescent shrub. 2. *Decodon*.

2. Herbaceous plants.

3. Flowers irregular; calyx spurred at base 7. *Cuphea*.

3. Flowers regular; calyx not spurred at base.

4. Calyx cylindrical, elongated 3. *Lythrum*.

4. Calyx campanulate, becoming globose with age.

5. Flowers usually two or more in leaf axils; capsules bursting irregularly;
leaf bases auriculate 4. *Ammannia*.

5. Flowers solitary in leaf axils; capsules either indehiscent or regularly
dehiscent; leaf bases not auriculate.

6. Petals absent; plant a submerged aquatic; capsules indehiscent 5. *Didiplis*.

6. Petals present; plant terrestrial or of wet soil; capsules regularly
dehiscent 6. *Rotala*.

The paper by Graham (1964) is a useful general reference for the Lythraceae.

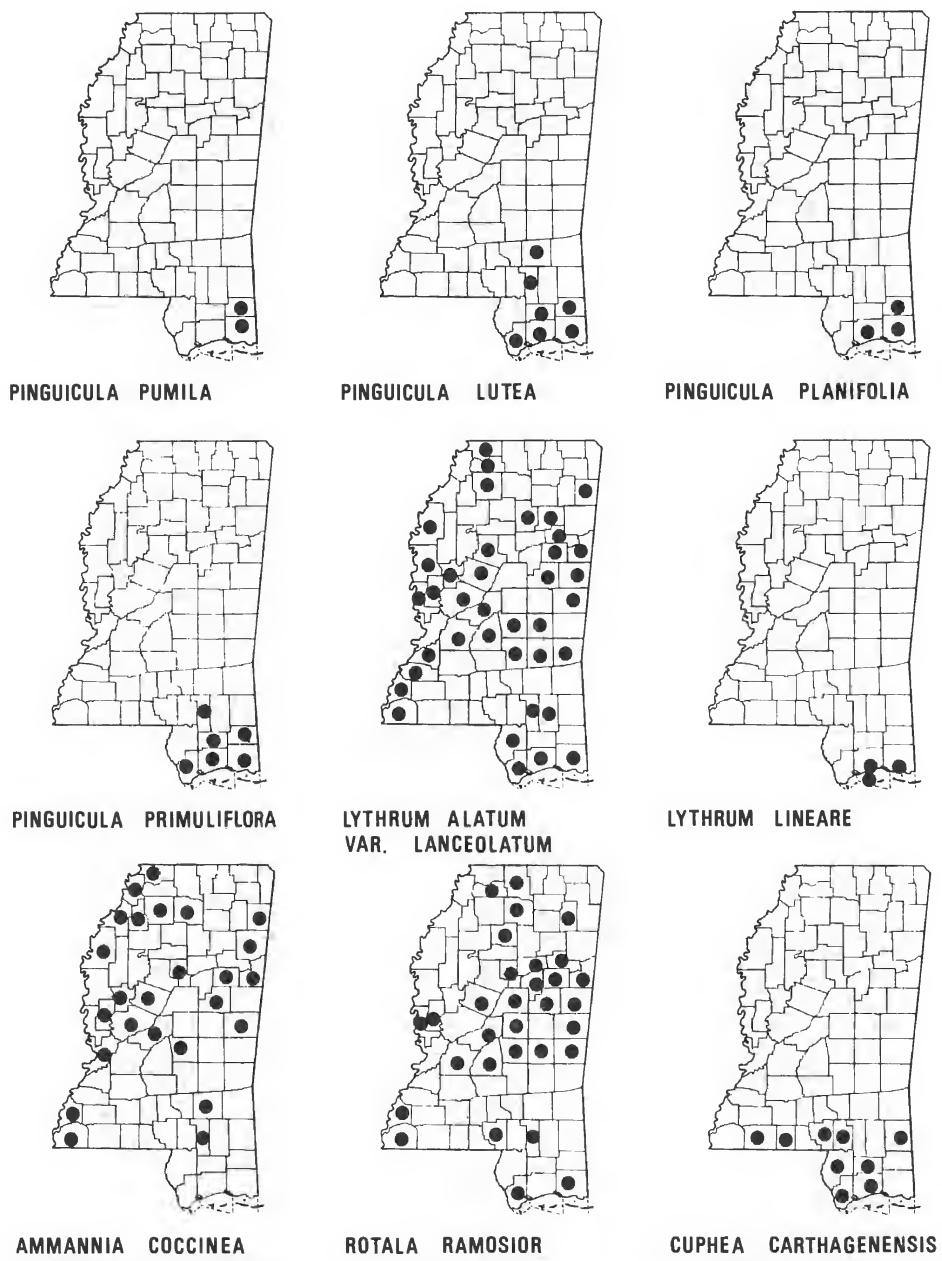


Figure 3. Distribution in Mississippi of *Pinguicula pumila*, *Pinguicula lutea*, *Pinguicula planifolia*, *Pinguicula primuliflora*, *Lythrum alatum* var. *lanceolatum*, *Lythrum lineare*, *Ammannia coccinea*, *Rotala ramosior*, and *Cuphea carthagenensis*.

1. LAGERSTROEMIA L. CRAPE MYRTLE

1. *L. indica* L., July—Sept. An attractive Old World shrub that is widely cultivated for its showy flowers, occurring about abandoned house sites; throughout.

2. DECODON J. F. Gmel.

1. *D. verticillatus* (L.) Ell., SWAMP-LOOSESTRIFE, WATER WILLOW. July—Oct. Bogs, swamps, margins of lakes; NCP, one old collection from Lauderdale County. The site was visited several times but this species was not seen; it should be looked for in the vicinity of Lauderdale Springs and elsewhere in east-central Mississippi.

3. LYTHRUM L. LOOSESTRIFE

1. Stem leaves widest at the base, more or less clasping	1a. <i>L. alatum</i> var. <i>alatum</i> .
1. Stems narrowed at the base, attenuate, not clasping.	
2. Stem leaves lanceolate, bracteal leaves usually alternate; mostly inland, sometimes near the coast	1b. <i>L. alatum</i> var. <i>lanceolatum</i> .
2. Stem leaves linear, bracteal leaves usually opposite; only along the coast	2. <i>L. lineare</i> .
1a. <i>L. alatum</i> Pursh var. <i>alatum</i> , June—July. Roadside; LBH, Desoto County.	
1b. <i>L. alatum</i> Pursh var. <i>lanceolatum</i> (Ell.) T. & G., June—Aug. Roadsides, bottomlands, prairies, fields; throughout.	
Fig. 3. <i>L. lanceolatum</i> —R.	
2. <i>L. lineare</i> L., July—Aug. Salt marshes, and sandy areas along the Coast. Fig. 3.	
Adapted from treatments by Graham (personal communication) and Shinners (1953).	

4. AMMANNIA L.

1. Style over 1.5 mm long	1. <i>A. coccinea</i> .
1. Style about 0.5 mm long	2. <i>A. latifolia</i> .
1. <i>A. coccinea</i> Rottb., July—Sept. Ditches, swamps, around the margins of ponds; throughout. Fig. 3.	
2. <i>A. latifolia</i> L., July—Sept. Tidal marshes, Jackson Co. Shirley A. Graham (personal communication) has seen one specimen from Mississippi: <i>Tracy 6424</i> , Horn Island, Jackson County. <i>A. koehnei</i> Britt.—S; <i>A. teres</i> Raf.—R.	

5. DIDIPLIS Raf. WATER PURSLANE

1. *D. diandra* (Nutt.) Wood, May—Sept. Roadside ditches, marshes, pools, ponds; NCP, Kemper and Newton Counties. *Peplis diandra* Nutt.—R. Shirley Graham (personal communication) indicated that the generic status of *Didiplis* vs. *Peplis* is an unknown; however, she feels that on the basis of the arguments in *Flora Europaea* and on pollen differences that ours should be called *Didiplis*.

6. ROTALA L. TOOTHCUP

1. *R. ramosior* (L.) Koehne, July—Sept. Ditches, margins of ponds; throughout. Fig. 3.

7. CUPHEA P. Br. WAXWEED

1. *C. carthagrenensis* (Jacq.) Macbr., July—Sept. Wet or moist soil along rivers, in bottomland forests, bogs, low roadsides; LPR, CPM. *Parsonia balsamona* (C. & S.) Standl.—S. Fig. 3.

NYMPHAEACEAE

1. Submersed leaves palmately dissected; floating leaves small, peltate; stamens 3—6	1. <i>Cabomba</i> .
1. Submersed leaves absent; floating or emersed leaves entire or nearly so; stamens many.	
2. Leaves peltate, without a basal sinus.	
3. Plants heavily coated with mucilage; perianth dull purple, 2—3 cm wide	2. <i>Brasenia</i> .

3. Plants not coated with mucilage; perianth yellow or pink, 15–25 cm wide	3. <i>Nelumbo</i> .
2. Leaves not peltate, with a basal sinus.	
4. Sepals 4; petals 12 to many, white or yellow, conspicuous	4. <i>Nymphaea</i> .
4. Sepals 6; petals numerous, small and stamen-like, inconspicuous	5. <i>Nuphar</i> .

1. CABOMBA Aubl.

1. *C. caroliniana* Gray, FANWORT. June–Aug. Ponds, lakes, borrow pits, quiet streams; NCP. Fig. 4.
For additional information on *Cabomba* see Fassett (1953).

2. BRASENIA Schreb.

2. *B. schreberi* J. F. Gmel., WATER-SHIELD. June–Aug. Lakes, ponds, slow streams; LPR, common and often weedy. The stems, petioles and lower leaf surfaces are heavily coated with a sticky mucilage. Fig. 4.

3. NELUMBO Adans.

1. Petals yellow	1. <i>N. lutea</i> .
1. Petals pink	2. <i>N. nucifera</i> .

1. *N. lutea* (Willd.) Pers., YELLOW LOTUS, POND-NUT, WATER-CHINQUAPIN. June–Aug. Emergent in shallow lakes, ditches; scattered locations throughout. The tubers and seed are edible and were used as food by Indians. Fig. 4.

2. *N. nucifera* Gaertn., SACRED LOTUS. June–Aug. Emergent in shallow lakes; locally spreading from cultivation, Hinds Co.

4. NYMPHAEA L. WATER-LILIES

1. Petals yellow	1. <i>N. mexicana</i> .
1. Petals white	2. <i>N. odorata</i> .

1. *N. mexicana* Zucc., YELLOW WATER LILY. May–Aug. Lakes, ponds; along the coast. Ken Rogers (personal communication) stated that he collected this species in a pond at Ocean Springs, Jackson Co., but I have not seen this collection.

2. *N. odorata* Ait., WHITE WATER LILY. Apr.–Sept. Ponds, lakes, bayous, slow moving streams; NPB, LPR, CPM, common and often a troublesome aquatic weed. *Castalia odorata* (Ait.) Woodv. & Wood; *C. minor* (Sims) DC.; *C. lekophylla* Small—S. Fig. 4.

For general information on the water-lilies see Small (1931).

5. NUPHAR Sm.

1. *N. luteum* (L.) Sibth. & Sm. ssp. *macrophyllum* (Small) E. O. Beal, YELLOW WATER-LILY, YELLOW COW-LILY, YELLOW POND-LILY, SPATTERDOCK. June–Sept. Lakes, ponds, streams, bayous; NPB, LPR, CPM. *Nymphaea advena* Ait., *N. macrophylla* Small—S; *Nuphar advena* (Ait.) Ait.f.—F, G. Fig. 4.

This treatment is based upon that of Beal (1956); additional information on variation in *Nuphar* can be found in DePoe and Beal (1969).

PODOSTEMACEAE

1. PODOSTEMOM Michx. RIVERWEED

1. *P. ceratophyllum* Michx., June–Nov. Attached to rocks in streams; TRH, Tishomingo Co., hearsay reports in the Leaf, Chunky, and Strong River systems. *P. abrotanoides* Nutt.—S.

POLYGONACEAE

1. Plant a woody vine; tendrils present at the tips of branches	1. <i>Brunnichia</i> .
1. Plant not a woody vine; tendrils absent at the tips of the branches.	
2. Branches appearing internodal	2. <i>Polygonella</i> .

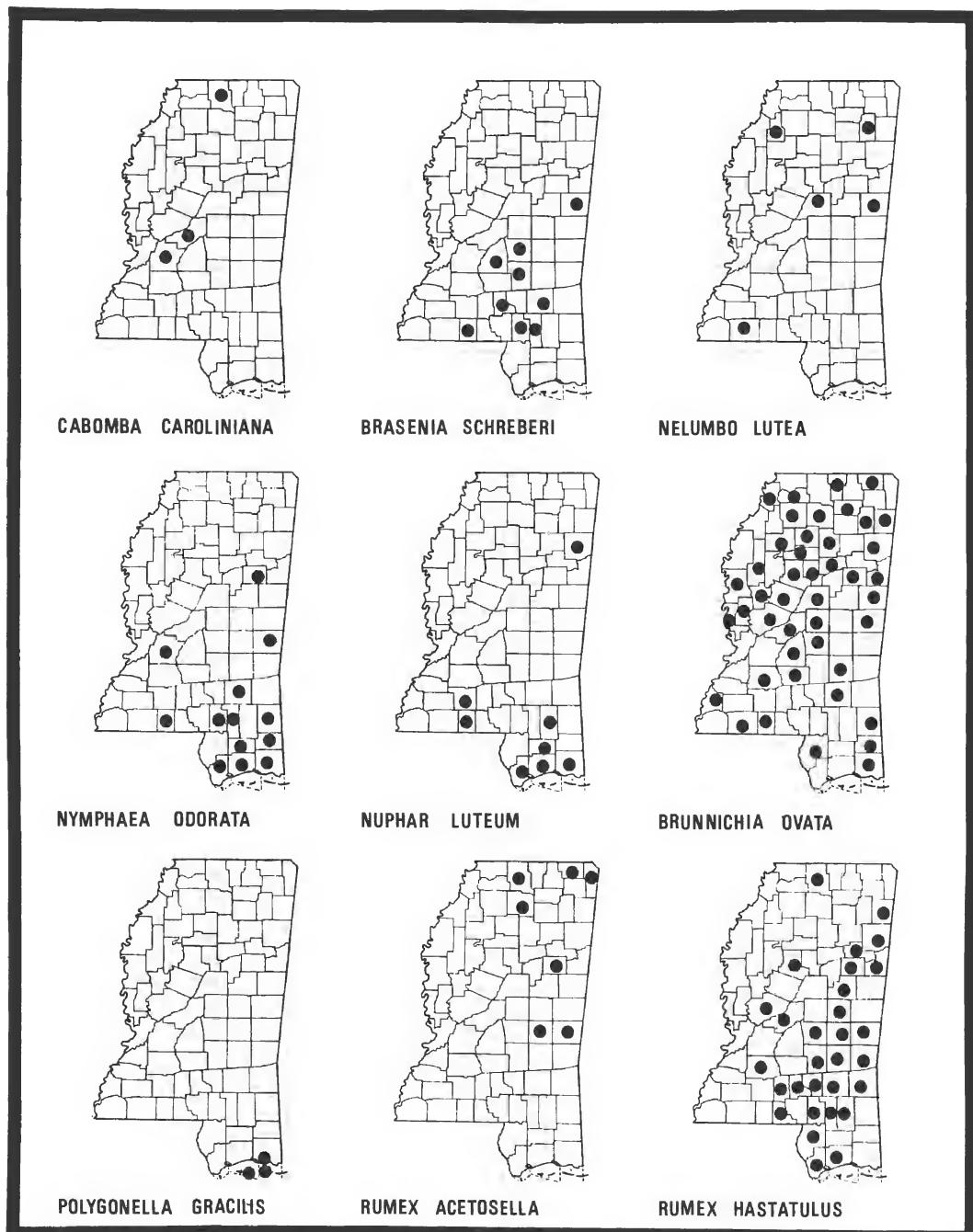


Figure 4. Distribution in Mississippi of *Cabomba caroliniana*, *Brasenia schreberi*, *Nelumbo lutea*, *Nymphaea odorata*, *Nuphar luteum*, *Brunnichia ovata*, *Polygonella gracilis*, *Rumex acetosella*, and *Rumex hastatulus*.

2. Branches appearing nodal.
3. Sepals 6; the inner 3 sepals longer and enlarged in fruit; a basal cluster of leaves usually present
3. Sepals usually 4 or 5, but, if 6, then the flowers not occurring in many-flowered inflorescences; sepals nearly equal in length in fruit or the inner sepals slightly smaller; a basal cluster of leaves usually not present

A good general reference on the family in the southeastern United States is the paper by Graham and Wood (1965).

3. *Rumex*.
4. *Polygonum*.

1. BRUNNICHIA Banks

1. *B. ovata* (Walt.) Shinners, LADIES-EARDROPS, EARDROP VINE, BUCKWHEAT VINE. June-July. Low woods, roadsides; common and abundant throughout. *B. cirrhosa* Banks ex Gaertn.—R, F, G, S. Fig. 4.

2. POLYGONELLA Michx. JOINTWEED

1. Plant perennial; leaves persistent on fruiting branches; outer sepals becoming reflexed during anthesis
1. Plant annual; leaves mostly deciduous before fruiting; outer sepals appressed during and after anthesis

1. *P. polygama* (Vent.) Engelm. & Gray, Aug.-Nov. Sandy soil of roadsides, wasteplaces, sand ridges; LPR, Perry Co. *P. croomi* Chapm.; *P. brachystachya* Meisn.—S.
2. *P. gracilis* (Nutt.) Meisn., Aug.-Nov. Sandy soil of roadsides, sand ridges, pinelands, beaches; along the coast. *Delopyrum gracile* (Nutt.) Small; *D. filiforme* Small—S. Fig. 4.

This treatment was adapted from that by Horton (1963).

3. RUMEX L. DOCK

1. Leaves usually hastate or sagittate; usually dioecious.
2. Plant perennial by rhizomes; inner sepals not larger than the achenes
2. Plant a winter annual or short lived perennial without rhizomes; inner sepals becoming much larger than the achene
1. Leaves not hastate or sagittate; flowers usually bisexual.
3. Inner sepals little if any wider than the face of the achene
3. Inner sepals notably wider than the achene.
4. Inner sepals toothed.
 5. Whorls of flowers well separated; pedicels about equal to or shorter than the calyx in fruit
 5. Whorls of flowers almost touching; pedicels longer than the mature calyx
4. Inner sepals with entire or undulate margins.
 6. Pedicels 2-5 times as long as the mature flower
 6. Pedicels seldom more than twice as long as the mature flower.
 7. Leaves with wavy crisp margins, usually lanceolate
 7. Leaves flat, without wavy crisp margins, broadly ovate-lanceolate

1. *R. acetosella* L., SHEEP SORREL. Mar.-June. Pastures, fields, roadsides, waste places; NCP, TRH. *Acetosella acetosella* (L.) Small—S. Fig. 4.
2. *R. hastatus* Baldw. ex Ell., HEART SORREL, RED SORREL. Mar.-May. A common weed of sandy fallow fields, roadsides, waste places; throughout except YMD. Fig. 4.
3. *R. conglomeratus* Murr., May-June. Waste places, pastures; NCP, YMD. Humphreys and Montgomery Counties.
4. *R. pulcher* L., FIDDLE DOCK. May-July. Pastures, roadsides, waste places; throughout, a common weed. Fig. 5.
5. *R. obtusifolius* L., May-Aug. Pastures, roadsides, wasteplaces; infrequent; scattered throughout. Fig. 5.
6. *R. verticillatus* L., SWAMP DOCK. May-Aug. Low places, wet meadows, NCP, LBH, YMD. Fig. 5.
7. *R. crispus* L., YELLOW DOCK, CURLY DOCK. Apr.-July. Pastures, lawns, small grains, wasteplaces, roadsides; throughout, an abundant and troublesome weed especially in pastures and small grains. Fig. 5.
8. *R. altissimus* Wood, PALE DOCK, SMOOTH DOCK. Apr.-Aug. Roadsides, waste places, pastures, often in low areas; throughout. Fig. 5.

This treatment was adapted from that of Rechinger (1937).

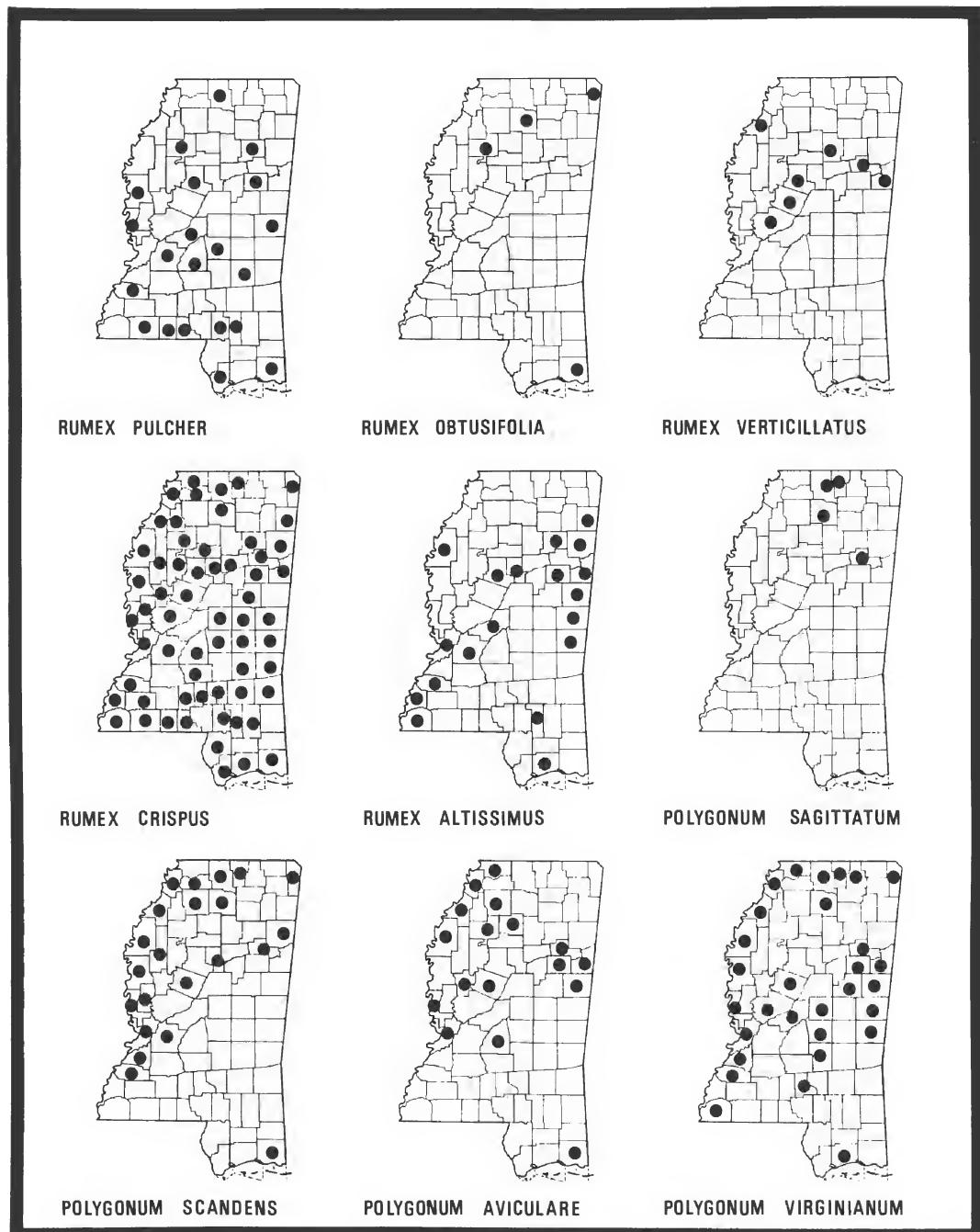


Figure 5. Distribution in Mississippi of *Rumex pulcher*, *Rumex obtusifolia*, *Rumex verticillatus*, *Rumex crispus*, *Rumex altissimus*, *Polygonum sagittatum*, *Polygonum scandens*, *Polygonum aviculare*, and *Polygonum virginianum*.

4. POLYGONUM L. SMARTWEED, KNOTWEED

1. Stems armed with prickles

1. Stems not armed with prickles.

2. Stems climbing
2. Stems not climbing.
 3. Flowers in clusters of 1–3 appearing at the base of the leaves in short clusters in their axils.
 4. Leaves yellow green; principal stem leaves more than 5 mm wide
 4. Leaves glaucous or bluish green; principal stem leaves usually less than 5 mm wide
 3. Flowers several to many in dense or loose elongated inflorescences arising at the ends of the stems and branches.
 5. Styles 2-cleft, persistent, deflexed at maturity
 5. Styles 2 or 3 cleft, deciduous at maturity.
 6. Leaves broadly ovate, often heart shaped or broadly rounded at the base.
 7. Leaves floating, glabrous; plant aquatic
 7. Leaves not floating, pubescent; plant not aquatic.
 8. Stems with soft spreading hairs; leaves soft hairy beneath
 8. Stems glabrous or with appressed hairs; leaves glabrous or with appressed hairs
 6. Leaves lanceolate, linear, or oblong, tapered or narrowed to slightly rounded at the base.
 9. Ocreae not ciliate or with cilia less than 0.5 mm long.
 10. Peduncles stipitate glandular or sometimes setose just below the inflorescence; sepals with irregularly forked nerves.
 11. Styles and stamens included within the calyx; achenes with both faces convex, 2.5–3.1 mm long
 11. Styles and/or stamens protruding from calyx; achenes with one face concave, 3–4.7 mm long
 10. Peduncles either glabrous or with sessile glands just below the inflorescence; sepals strongly 3-nerved, each nerve terminating in an anchor-shaped fork
 9. Ocreae with cilia more than 0.5 mm long.
 12. Calyx glandular-punctate.
 13. Achenes dull
 13. Achenes shining
 12. Calyx not glandular-punctate.
 14. Plants perennial from woody rhizomes.
 15. Leaves usually strigose, usually 15 mm or more wide
 15. Leaves usually glabrous, usually less than 15 mm wide
 14. Plants annual.
 16. Ocreae cilia up to 4 mm long, less than 1/2 as long as the ocreae; achenes 2–2.5 mm long
 16. Ocreae cilia more than 5 mm long, more than 1/2 as long as the ocreae; achenes 1.5–2.1 mm long

1. *P. sagittatum* L., TEAR-THUMB. July–Oct. Wet soil around ponds, along streams; NCP, NPB. *Tracaulon sagittatum* (L.) Small—S. Fig. 5.

2. *P. scandens* L., CLIMBING BUCKWHEAT. July–Oct. Low woods; throughout. *Bilderdykia scandens* (L.) Greene; *B. cristata* (Engelm. & Gray) Greene; *B. dumetorum* (L.) Dum.—S; *P. cristatum* Engelm. & Gray—F; *P. scandens* var. *dumetorum* (L.) Gl.—G, Fig. 5.

3. *P. erectum* L., June–Oct. Waste places; Oktibbeh Co.

4. *P. aviculare* L., sens. lat. Knotweed. May–Oct. Dry waste places; YMD, LBH, NCP, NPB. Fig. 5. *P. neglectum* Bess.; *P. buxiforme* Small—S. (see Mertens and Raven 1965).

5. *P. virginianum* L., JUMPSEED. July–Oct. Rich woods, alluvial forests; throughout. *Tovara virginiana* (L.) Raf.—R, S. Li (1952) presented a good argument for the separation of *P. virginianum* from *Polygonum* citing: the number of calyx lobes; the fact that the calyx lobes enlarge but little, if any, in fruit; the hooked style branches; and the peculiar

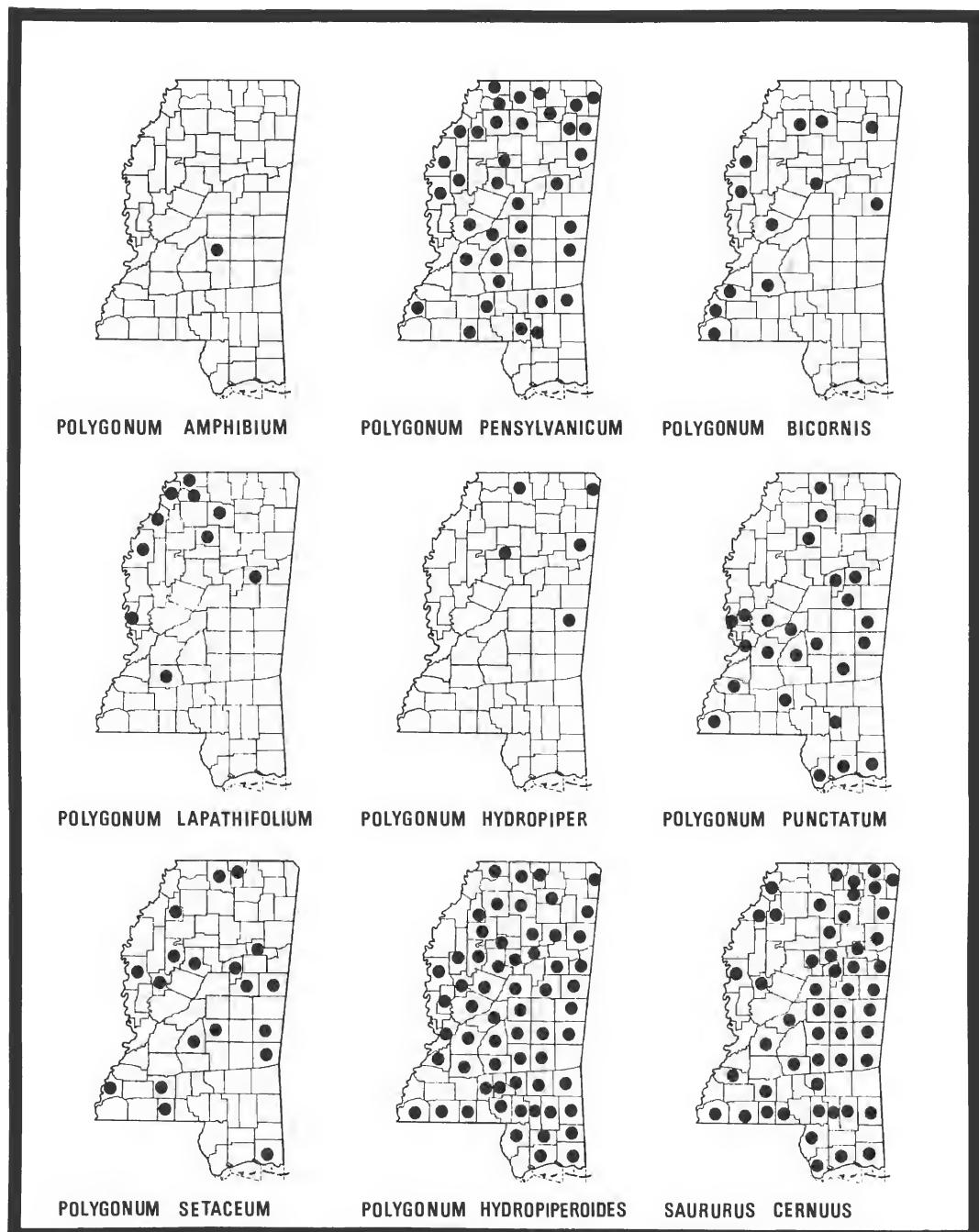


Figure 6. Distribution in Mississippi of *Polygonum amphibium*, *Polygonum pensylvanicum*, *Polygonum bicornis*, *Polygonum lapathifolium*, *Polygonum hydropiper*, *Polygonum punctatum*, *Polygonum setaceum*, *Polygonum hydropiperoides*, and *Saururus cernuus*.

inflorescences. If segregated, the name should be *Antenorion virginianum* (L.) Roberty & Vautier, since *Tovaria* is not valid. Fig. 5.

6. *P. amphibium* L. WATER SMARTWEED. July—Oct. Margins of swamps, lakes, rare; JP, Scott Co. A highly variable species. *Persicaria muhlenbergii* (Meisn.) Small—S; *P. coccineum* Muhl. ex Willd.—R, G, F. (see Mitchell 1968). Fig. 6.

7. *P. orientale* L., KISS-ME-OVER-THE-GARDEN-GATE, PRINCESS-FEATHER. July—Oct. Sometimes escaping from cultivation to waste places; YMD, Washington Co. *Persicaria orientalis* (L.) Spach.—S.

8. *P. pensylvanicum* L., PINKWEED. June—Oct. Fields, waste places; common throughout except CPM; often troublesome. *Persicaria pensylvanica* (L.) Small.—S. Fig. 6.

9. *P. bicornis* (Raf.) Nieuw., July—Oct. Low ground near streams; throughout, except LPR, CPM. *Persicaria mississippiensis* (Stanford) Small; *Persicaria longistyla* Small—S; *Polygonum longistylum* Small—F, G. Fig. 6.

10. *P. lapathifolium* L., July—Oct. Alluvial fields, waste places; mainly YMD. *Persicaria lapathifolia* (L.) S. F. Gray—S. Fig. 6.

11. *P. hydropiper* L., WATER PEPPER. June—Oct. Alluvial fields, waste places; NCP, TRH, NPB. *Persicaria hydro-piper* (L.) Opiz.—S. Fig. 6.

12. *P. punctatum* Ell., WATER SMARTWEED. July—Oct. Alluvial fields, wet places, ditches; common throughout. *Persicaria punctata* (Ell.) Small—S. (see Fassett 1949). Fig. 6.

13. *P. setaceum* Baldw. ex Ell., July—Oct. Alluvial woods; throughout. *Persicaria setacea* (Baldw.) Small—S; *Polygonum hydropiperoides* var. *setaceum* (Baldw.) Gl.—G. Fig. 6.

14. *P. hydropiperoides* Michx., July—Oct. Margins of swamps, streams, ditches, lakes; common and abundant throughout. *Persicaria hydropiperoides* (Michx.) Small; *P. opelousana* (Ridd.) Small—S; *Polygonum opelousanum* Ridd.—G, F; *P. hydropiperoides* var. *opelousanum* (Ridd. ex Small) Stone—R. Fig. 6.

15. *P. persicaria* L., June—Oct. Waste places; NCP, NPB, Carroll and Oktibbeha Counties. *Persicaria persicaria* (L.) Small—S.

16. *P. cespitosum* Blume., June—Oct. Alluvial fields, moist soil around ponds; NCP, Madison Co.

SAURURACEAE

1. SAURURUS L.

1. *S. cernuus* L., LIZARD'S TAIL. June—Sept. In shallow water or muddy soils of low woods, swamps; throughout. Fig. 6.

ACKNOWLEDGEMENTS

Support for the field work, begun in 1964, was provided by two National Science Foundation research grants to the Mississippi Flora project, and later support was provided to me by the University of Georgia. Drs. Tom Pullen and Ray Watson are my co-investigators on the Mississippi Flora project; Lionel Eleuterius of the Gulf Coast Research Laboratory helped in many ways, especially with the coastal plants; and

F. H. Sargent and Ken Rogers made many good collections; the first draft of this treatment was read and criticized by A. E. Radford; the Polygonaceae was edited by J. H. Horton; Shirley A. Graham provided helpful comments on the Lythraceae; and Ms. Mary Ann Keller and later Ms. Katie Chancey both patiently prepared the typescript for this manuscript. I am indebted to all of these individuals and to many others who have made this work possible.

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Gulf Research Reports

Volume 5 | Issue 1

January 1975

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DOI: 10.18785/grr.0501.04

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Burke, W. 1975. Pelagic Cnidaria of Mississippi Sound and Adjacent Waters. *Gulf Research Reports* 5 (1): 23-38.
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PELAGIC CNIDARIA OF MISSISSIPPI SOUND AND ADJACENT WATERS¹

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ABSTRACT Investigations were made in Mississippi Sound and adjacent waters from March 1968 through March 1971 to record the occurrence and seasonality of planktonic cnidarians. About 700 plankton samples were taken from estuarine and oceanic areas. From these samples, 26 species of hydromedusae were identified, 12 of which were collected from Mississippi Sound. In addition, 25 species of siphonophorae were identified from Mississippi waters, although only 6 species were collected in Mississippi Sound. From an examination of about 500 trawl samples taken during this period, 10 species of Scyphozoa were found in Mississippi waters, 6 of which occurred in Mississippi Sound.

INTRODUCTION

Plankton samples taken from the shallow waters of Mississippi Sound frequently disclose large numbers of hydromedusae, and it is a rare sample that fails to contain cnidarians. Yet there is a paucity of published information concerning the seasonal composition and distribution of the coelenterates of Mississippi Sound or indeed of the entire northern Gulf of Mexico.

Mayer's (1900) work in the Tortugas was the first substantive catalogue of Cnidaria from a specific location within the Gulf of Mexico. Mayer's publication provided the data for Sears' (1954a) compilation of hydromedusae presumed to occur within the Gulf. Kramp (1959) catalogued the hydromedusae of the Atlantic coast of the United States and supposed that Atlantic cnidarian assemblages would not necessarily characterize Gulf of Mexico populations. The distribution of the anthomedusa *Nemopsis bachei* L. Agassiz 1849 along the northern Gulf of Mexico was discussed by Moore (1962). Hopkins (1966) published a comprehensive list of hydromedusae known to occur in St. Andrew Bay, Florida. Generally, however, most recent papers on zooplankton of the Gulf of Mexico have afforded the hydromedusae only cursory attention.

Although the littoral region of the northern Gulf of Mexico has a relatively rich scyphozoan fauna, workers in this part of the world have tended to treat these medusae in only a perfunctory manner. Hedgpeth (1954), drawing largely from Mayer (1900, 1910), produced a checklist of Scyphozoa likely to occur within the Gulf of Mexico. Guest (1959) and Phillips and Burke (1970) discussed the distribution of *Chiropsalmus quadrumanus* (Müller 1859) along the coasts of Texas and Mississippi respectively. Hoese et al. (1964) recorded *Cyanea capillata* (L.) as a faunal element at Port Aransas, Texas. Sanders and Sanders (1963) erected a tenuous subspecies of *Pelagia noctiluca* Forskål 1775 based on specimens collected near Galveston, Texas. Phillips et al. (1969) discussed the trophic significance of several species

of coelenterates from Mississippi waters. Several workers along the northern Gulf of Mexico have made reference to a few species of scyphomedusae occurring in their respective study areas (Whitten et al. 1950; Gunter 1950; Simmons 1957; Menzel 1971). Sears (1954b) briefly concluded that it would not be surprising to find in the Gulf of Mexico any one of the 140 or more siphonophore species now known.

THE WORK AREA: MISSISSIPPI SOUND

Mississippi Sound is an elongate, shallow body of water extending from Lake Borgne in Louisiana to Mobile Bay in Alabama, and is bounded to the south by a series of five low barrier islands. The shallowly submerged bars between the barrier islands are cut by several natural deep passes, and three channels into Mississippi Sound are maintained for navigation purposes. Five major watersheds introduce fresh water into Mississippi Sound. The sound is typically shallow (ca. 10 feet) and is subject to extreme variations of salinity and temperature. The bottom is soft mud except in the sandy areas adjacent to the barrier islands.

METHODS: PLANKTON SAMPLING

From March 1968 until August 1969 numerous stations in Mississippi Sound (Figure 1) were sampled at approximately monthly intervals. Surface samples were collected by towing an 18-inch zooplankton net, equipped with 330-micron netting, for 1 mile at each site. During the same period, monthly surface samples were taken in similar fashion offshore (Figure 2) using 1-meter plankton nets. August 1969 witnessed the onslaught of Hurricane Camille, which destroyed all project facilities, the backlog of unexamined samples, and all curated specimens. Routine monthly plankton sampling was resumed in January 1970 and continued through March 1971. At each of the stations indicated in Figure 3, monthly surface and bottom plankton samples were collected. Additional midwater plankton samples were regularly collected at stations 9 and 10. Standard 12-inch plankton nets were employed to obtain surface samples and 12-inch Clarke-Bumpus plankton samplers were used to obtain subsurface samples. All nets used subsequent to

¹This study was conducted in cooperation with the Department of Commerce, NOAA, National Marine Fisheries Service, under Public Law 89-720, Project No. JI-2-1.

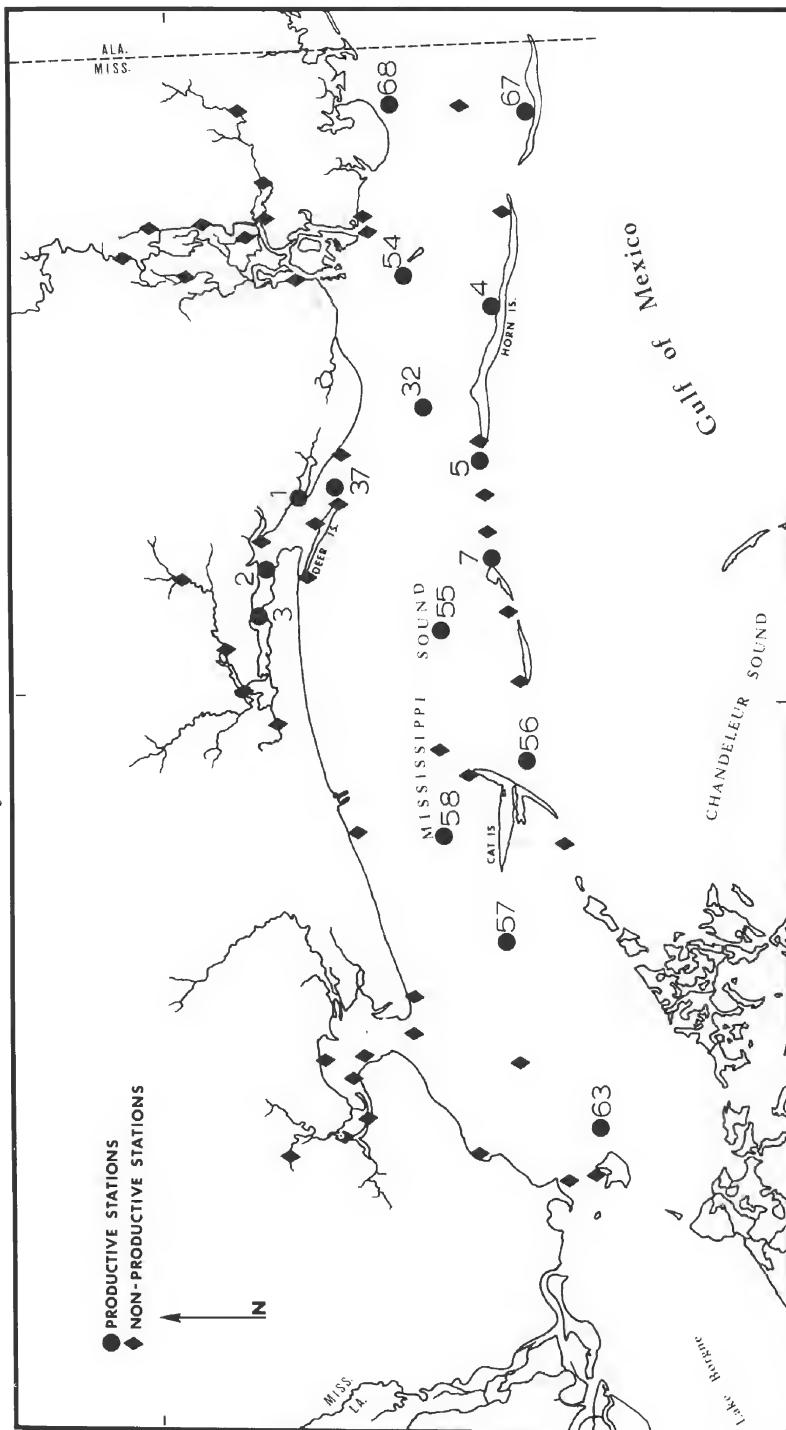


Figure 1. Sites of monthly surface plankton collections in Mississippi Sound, March 1968–August 1969.

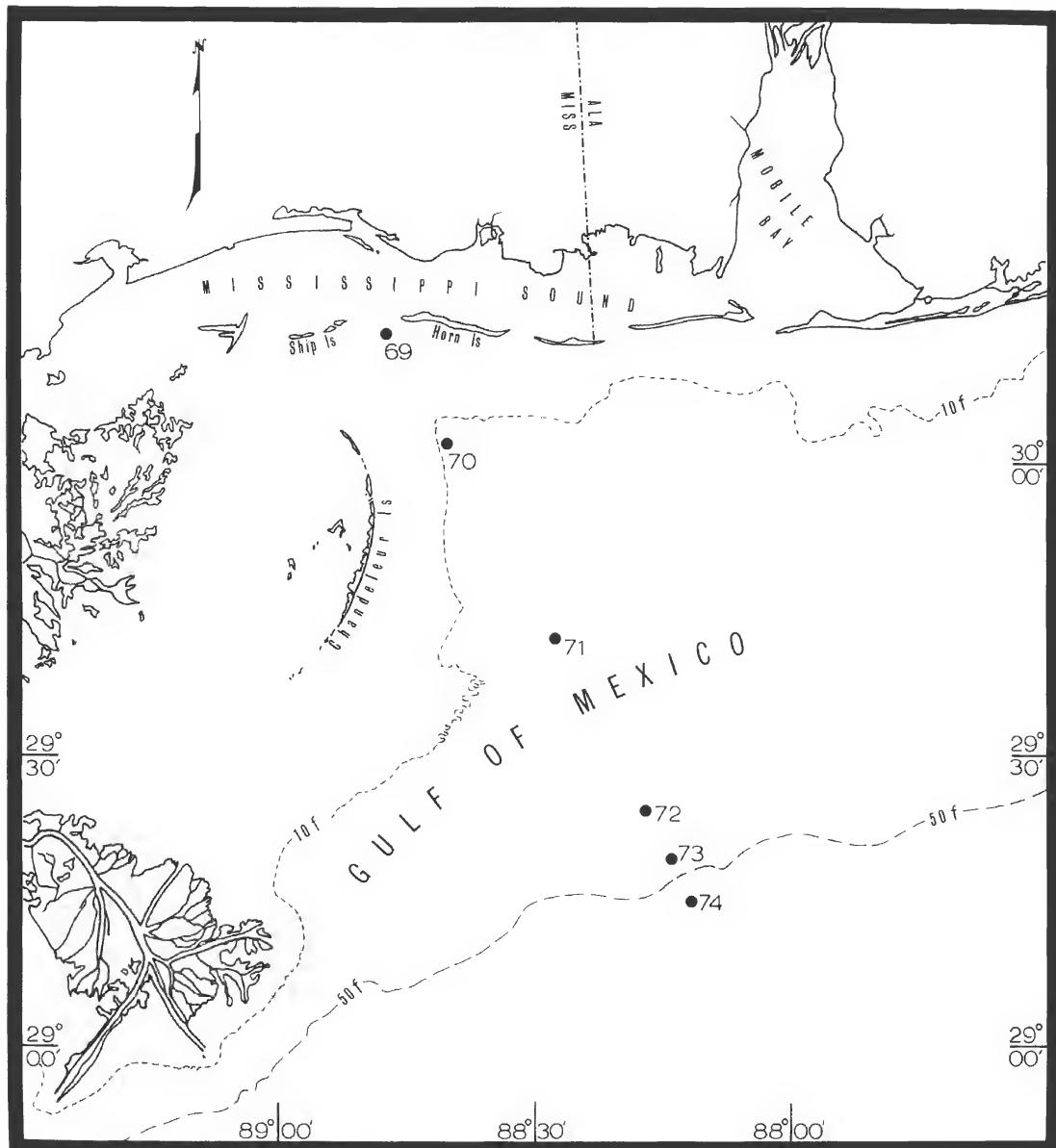


Figure 2. Sites of monthly surface plankton collections in the northern Gulf of Mexico, March 1968–August 1969.

January 1970 were equipped with No. 8 mesh (193 microns). Since it was necessary to trail the surface net a considerable distance behind the boat to avoid the tremendous wash produced by jet-pump propelled boats, yet at sufficiently great speed to prevent nets sinking very far below the surface, samples were collected at fairly high speeds. Nets were

operated at each collecting site for 10 minutes at a speed of 3 knots. All plankton samples collected during the 3-year period were preserved in 5% formalin-seawater solutions and were brought to the laboratory for analysis. Twenty-four-hour settled plankton volumes were determined for all samples and medusae were subsequently sorted, identified

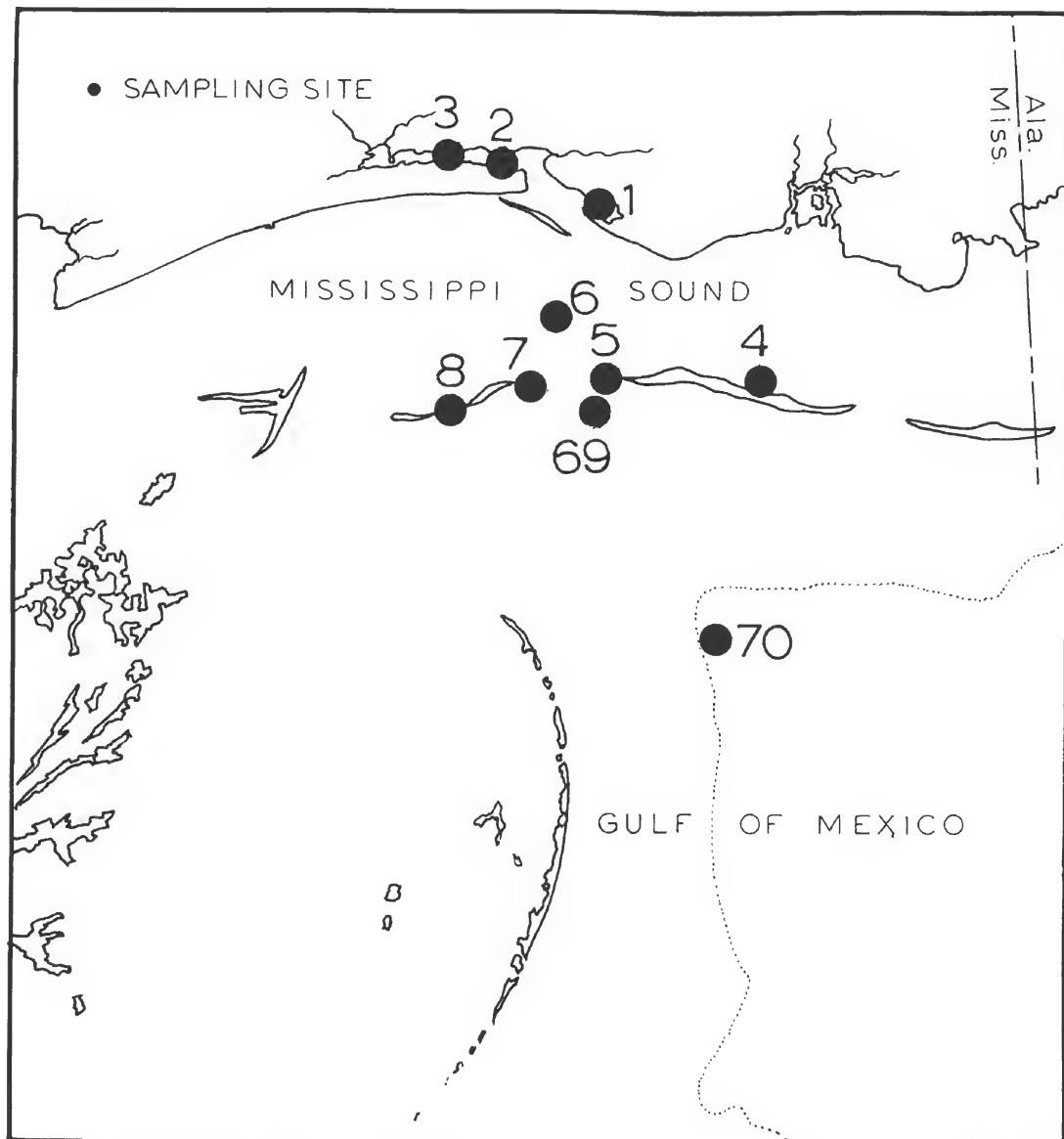


Figure 3. Sites of monthly bottom trawl, surface, midwater and bottom plankton collections in Mississippi Sound and the adjacent Gulf of Mexico, January 1970–March 1971.

and curated. Species determinations were largely based on the works of Mayer (1910) and Kramp (1959).

METHODS: SCYPHOMEDUSAE SAMPLING

Concurrent with each inshore plankton sampling effort,

larger medusae were routinely collected with bottom trawls. Otter trawls employed at inshore stations were 16 feet wide semi-balloons made of 1-inch stretch nylon, and were dragged for 10 minutes at a speed of 3 knots. Larger nets were dragged a distance of 1 mile at offshore sampling sites. Discrepancies between the sampling procedures employed in

the two areas essentially precluded quantitative analyses but did serve to provide data of qualitative nature.

Additional specimens of scyphomedusae were collected by dipnetting or by gathering specimens stranded along the swash lines of the mainland and along the beaches of the several islands.

DREDGING OPERATIONS

During the late summer of 1968 and again during the summer of 1970, dredge samples were taken from 118 stations near the mouth of the Mississippi River, throughout the Chandeleur Islands in Louisiana and within Mobile Bay, Alabama. These dredge samples were meticulously examined for the sessile stages of Cnidaria. No scyphozoan polyps and only seven species of hydroids were present. The silt-laden waters characteristic of Mississippi Sound are likely inimical to polyp production. However, if viable polyp beds ever existed in or near Mississippi Sound, they would have likely been buried by the force of the August 1969 hurricane, and presumably would not be re-established for several seasons.

HYDROLOGICAL TECHNIQUES

Hydrologic data were collected at levels corresponding to biological sampling activity. Temperature, salinity and dissolved oxygen were routinely determined in the field with portable instruments. Occasional failure of instrumentation dictated that parameters would be determined in the field with hand-held or reversing thermometers, and Goldberg refractometers. Some water samples were collected, chilled on ice, and brought to the laboratory where dissolved oxygen and pH were determined by appropriate laboratory procedures. Additionally, water transparency of each collecting site was estimated by observing extinction points of standard Secchi discs. Although all parameters were seasonally, areally and vertically variable it was statistically demonstrable that neither transparency, pH nor dissolved oxygen was a factor in limiting the distribution of any given species of medusa.

Critical oxygen concentrations or pH values were found only in freshwater areas subject to industrial or domestic pollution.

Temperatures followed a fairly predictable seasonal cycle averaging about 10°C during winter and about 30°C in summer. Temperature extremes of 7.7°C and 32.7°C were observed during the study period.

Salinities ranged from fresh in the upper bay areas to oceanic at the offshore stations. Salinity throughout most of the sound is subject to considerable local variations determined by prevailing wind conditions, rainfall and subsequent river discharge. Salinity extremes of 0.4 ppt and 37.7 ppt were encountered during the study period.

RESULTS

Sixty-one species of cnidarians were collected from Mississippi Sound and the adjacent Gulf of Mexico. Open Gulf waters south of the barrier islands displayed considerably greater faunal diversity than the relatively impoverished sound. Present in the samples were 26 species of hydro-

medusae, 25 species of siphonophores, and 10 species of scyphomedusae.

Among the few species of hydromedusae found to be capable of long-term survival in Mississippi Sound were *Liriope tetraphylla* (Chamisso and Eysenhardt 1821), *Nemopsis bachei* L. Agassiz 1849, *Bougainvillia carolinensis* (McCrady 1857), and *Persa incolorata* McCrady 1857. These four species were often so abundant in Mississippi Sound as to represent the bulk of a given plankton sample. *L. tetraphylla*, the most abundant hydromedusa in Mississippi Sound, displayed an affinity for warm, high-salinity water masses and apparently occurred in Mississippi Sound as a result of the intrusion of Gulf waters during summers. *P. incolorata*, although associated with fairly high marine masses, displayed a considerable tolerance to variations in temperature, occurring at temperatures ranging from below 10°C to about 30°C. *Persa* was found to be abundant in the island passes from midwinter through late summer.

The anthomedusa *N. bachei* displayed the ability to survive a wide range of both salinity and temperature. *Nemopsis* was the only hydromedusa regularly collected in brackish water (ca. 5 ppt salinity), and occurred in Mississippi Sound from late fall through early spring. *B. carolinensis*, although not as eurytropic as *N. bachei*, was abundant in Mississippi Sound during all but the midwinter months. *B. carolinensis* occurred year-round in the northern Gulf adjacent to the sound.

Generally, hydromedusae were more abundant at salinities between 25 and 30 ppt. There was a gradual decline in numbers with decreasing salinities, and a marked decline with increasing salinities. Under conditions of higher salinities hydromedusae were apparently ecologically displaced by the oceanic siphonophores. Presumably the bulk of both hydromedusae and scyphomedusae were recruited into Mississippi Sound from the Gulf of Mexico as adults or near adults.

In Mississippi Sound, hydromedusae were generally more numerous at higher temperatures, achieving maximum numbers during the summers and declining drastically during the winters. Offshore, where environmental conditions were somewhat more stable, populations were fairly constant year-round. Vertical stratification of hydromedusae was not demonstrable in either Mississippi Sound or the immediately adjacent Gulf of Mexico. There was no direct correlation between numbers of hydromedusae and the volume of residual planktonic elements within given plankton samples, suggesting that in an area as placid as Mississippi Sound frequently becomes, hydromedusae are not strictly planktonic but are capable of exhibiting a nearly nektonic mode of life.

The areal and seasonal distributions of all species of hydromedusae collected in Mississippi Sound are indicated in Tables 1 and 2 respectively.

Diagnoses, previous geographic distributions, and line drawings of all species of hydromedusae known to occur in Mississippi waters are given in the following section. The diagnoses and distributions are those of P. L. Kramp (1959). The line drawings were executed by Harry L. Moore, Gulf Coast Research Laboratory, and are after various authors.

TABLE 1.

Medusae of 1968-1971 inshore and offshore plankton collections; Mississippi waters

Species	Inshore	Offshore
Class: Hydrozoa		
Order: Anthomedusae/Athecata		
<i>Amphinema dinema</i> (Péron & Lesueur 1809)		X
<i>Bougainvillia carolinensis</i> (McCrady 1857)	X	X
<i>Bougainvillia frondosa</i> Mayer 1900		X
<i>Cyanea tetrastyle</i> Eschscholtz 1829		X
<i>Dipurea ophiogaster</i> Haeckel 1879	X	X
<i>Euphyllora gracilis</i> (Brooks 1882)	X	X
<i>Hybocodon forbesi</i> Mayer 1894		X
<i>Lizia gracilis</i> (Mayer 1900)		X
<i>Nemopsis bachei</i> L. Agassiz 1849	X	X
<i>Stenostiria nutans</i> (M. Sars 1835)		X
Order: Leptomedusae/Thecata		
<i>Eirene pyramidalis</i> (L. Agassiz 1862)		X
<i>Eirene viridula</i> (Péron & Lesueur 1809)	X	X
<i>Eutima mira</i> McCrady 1857	X	X
<i>Eutima variabilis</i> McCrady 1857	X	X
<i>Laodicea undulata</i> (Forbes & Goodsir 1853)		X
<i>Obelia</i> spp.	X	X
<i>Phialidium languidum</i> (A. Agassiz 1862)	X	X
Order: Trachymedusae		
<i>Aglaea hemistoma</i> Péron & Lesueur 1809		X
<i>Geryonia proboscivalis</i> (Forskål 1775)	X	
<i>Liriope tetraphylla</i> (Chamisso & Eysenhardt 1821)	X	X
<i>Persa incolorata</i> McCrady 1857	X	X
<i>Rhopalonema velatum</i> Gegenbaur 1856	X	
Order: Narcomedusae		
<i>Cunina octonaria</i> McCrady 1857	X	
<i>Cunina peregrina</i> Bigelow 1909	X	
<i>Solmundella bitentaculata</i> (Quoy & Gaimard 1833)	X	
Order: Limnomedusae		
<i>Proboscidactyla ornata</i> (McCrady 1857)		X
Order: Siphonophorae		
Sub-Order: Cystonectae		
<i>Physalia physalis</i> (L.)	X	X
<i>Rhizophysa filiformis</i> Forskål 1775		X
Sub-Order: Physonectae		
<i>Agalma okeni</i> Eschscholtz 1825	X	X
<i>Cordagama cordiformis</i> Totton 1932		X
<i>Nanomia bijuga</i> Chiappe 1841	X	X
Sub-Order: Calycophorae		
<i>Abylopsis eschscholtzi</i> Huxley 1859		X
<i>Abylopsis tetragona</i> Otto 1823		X
<i>Bassia bassensis</i> Quoy & Gaimard 1833	X	X
<i>Ceratocymba leukartii</i> (Huxley 1859)		X
<i>Ceratocymba sagittata</i> Quoy & Gaimard 1827	X	
<i>Chelophyes appendiculata</i> Eschscholtz 1829	X	X
<i>Diphyes bojani</i> Eschscholtz 1829		X
<i>Diphyes dispar</i> Chamisso & Eysenhardt 1821	X	

TABLE 1 - Continued

Species	Inshore	Offshore
Sub-Order: Calycophorae - Continued		
<i>Enneagonium hyalinum</i> Quoy & Gaimard 1827		
<i>Eudoxoides mitra</i> Huxley 1859		X
<i>Eudoxoides spiralis</i> Bigelow 1911		X
<i>Hippopodius hippopus</i> Forskål 1776		X
<i>Lensia campanella</i> Moser 1925		X
<i>Lensia subtilis</i> Chun 1886		X
<i>Muggiaeae kochi</i> Will 1844		X
<i>Sulceolaria biloba</i> Sars 1846		X
<i>Sulceolaria chuni</i> Lens & Van Riemsdijk 1908		X
<i>Sulceolaria quadrivalvis</i> Blainville 1834		X
<i>Vogria glabra</i> Bigelow 1918		X
Order: Chondrophora		
<i>Velella velella</i> (L.)		X
Class: Scyphozoa		
Order: Coronatae		
<i>Nautilus punctata</i> Kölliker 1853		X
<i>Paraphyllina</i> sp.		X
Order: Semaeostomeae		
<i>Aurelia aurita</i> (L.)		X
<i>Chrysaora quinquecirrha</i> (Desor 1848)		X
<i>Cyanea capillata</i> (L.)		X
<i>Pelagia noctiluca</i> Forskål 1775		X
Order: Cubomedusae		
<i>Chiropsalmus quadrumanus</i> (Müller 1859)		X
<i>Tamoya haplonema</i> Müller 1859		X
Order: Rhizostomeae		
<i>Rhopilema verrillii</i> (Fewkes 1887)		X
<i>Stomolophus meleagris</i> L. Agassiz 1862		X

DIAGNOSES AND ACCOUNTS OF CERTAIN OF THE MEDUSAE OF MISSISSIPPI WATERS:

HYDROZOA

CLASS HYDROZOA: Medusae with a velum or membrane, which partially closes the marginal opening of the bell. Reproductive organs ectodermal. Development direct or alternating with a sessile hydroid, neither stage possessing gastric filaments or ridges.

Order 1. Anthomedusae/Athecata: Hydromedusae with gonads typically on the manubrium. No lithocysts, may possess photoreceptors (ocelli). Umbrella usually deep bell-shaped.

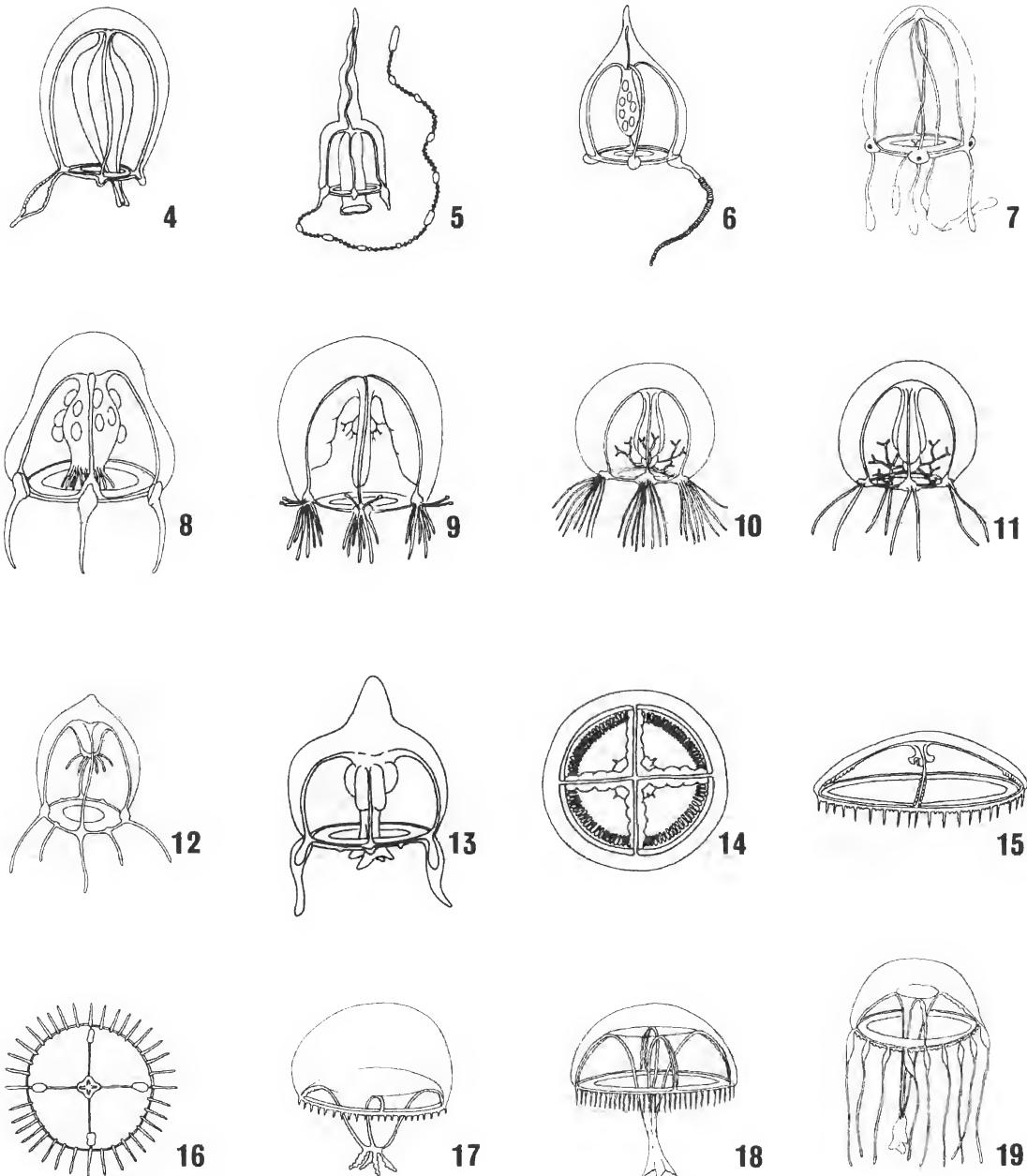
Family 1. Tubulariidae: Anthomedusae with simple tubular mouth; 4 radial canals; short manubrium; 1-4 tentacles, alike or dissimilar; no ocelli. Three representative species in Mississippi waters:

Hybocodon forbesi Mayer 1894 (Figure 4)

Euphyllora gracilis (Brooks 1882) (Figure 5)

Stenostiria nutans (M. Sars 1835) (Figure 6)

Diagnosis: *Hybocodon forbesi*. 3 mm high, bell-shaped, jelly uniformly thin. With short manubrium; 4 radial canals;



Figures 4-19. 4. *Hybocodon forbesi* Mayer 1894. 5. *Euphydora gracilis* (Brooks 1882). 6. *Stenstrupia nutans* (M. Sars 1835). 7. *Dipurena ophiogaster* Haeckel 1879. 8. *Cyaneis tetrastyla* Eschscholtz 1829. 9. *Nemopsis bachei* L. Agassiz 1849. 10. *Bougainvillia carolinensis* (McCrady 1857). 11. *Bougainvillia frondosa* Mayer 1900. 12. *Lizia gracilis* (Mayer 1900). 13. *Amphinema dinema* (Péron & Lesueur 1809). 14. *Laodicea undulata* (Forbes & Goodsir 1853). Aboral view. 15. *Phialidium languidum* (A. Agassiz 1862). 16. *Obelia* sp. Oral view. 17. *Eirene pyramidalis* (L. Agassiz 1862). 18. *Eirene viridula* (Péron & Lesueur 1809). 19. *Eutima variabilis* McCrady 1857.

TABLE 2.

Seasonal occurrence of pelagic coelenterates in Mississippi Sound and adjacent waters, 1968-1971.
(+ = Mississippi Sound; * = open Gulf south of Mississippi Sound).

TABLE 2 (Continued).

Seasonal occurrence of pelagic coelenterates in Mississippi Sound and adjacent waters, 1968-1971.
(+ = Mississippi Sound; * = open Gulf south of Mississippi Sound).

1 well developed tentacle and 3 rudimentary knob-like tentacles.

Previous recorded distribution: Bahamas, Tortugas, India, Japan. Rare in Mississippi waters, one specimen collected at station 69 on 7 April 1971.

Diagnosis: *Euphyllora gracilis*. 5 mm high inclusive of prominent apical projection, bell slender, jelly thin. With massive manubrium, surrounded by the gonad; 4 radial canals; long cordlike major tentacle; opposite tentacle cone-shaped, the 2 others mere bulbs.

Previous recorded distribution: New England coast to Florida, Brazil. Common in Mississippi waters, occurs most months of the year both inshore and offshore.

Diagnosis: *Stenstrupia nutans*. 5 mm high inclusive of prominent apical projection. With massive manubrium, surrounded by gonad; 4 radial canals; major tentacle long, other 3 mere bulbs.

Previous recorded distribution: Northwestern Europe, Mediterranean Sea. Rare in Mississippi waters. One specimen collected on 17 January 1968 at station 71, and another on 27 March 1968 at station 74.

Family 2. Corynidae: Anthomedusae with simple tubular mouth; 4 radial canals; gonad surrounding the manubrium; usually 4 tentacles (occasionally only 2); ocelli present. One representative in Mississippi waters:

Dipurena ophiogaster Haeckel 1879 (Figure 7).

Diagnosis: 5 mm high, bell-shaped, jelly thick. With gonads in 2 to several segments along manubrium; 4 radial canals; 4 perradial tentacles; distinct apical chamber. Tentacles bulbs with ocelli.

Previous recorded distribution: Southern coast of Britain, Ceylon, Japan, west coast of Mexico. Rare in Mississippi waters. One specimen collected at station 69 on 14 August 1968; a second specimen collected at station 72 on 23 August 1968.

Family 3. Cytaeidae: Anthomedusae with simple mouths; unbranched oral tentacles or with 4 clusters of cnidophores; 4 radial canals; 4 solid marginal tentacles. One representative in Mississippi waters:

Cytaeis tetrastyla Eschscholtz 1829 (Figure 8).

Diagnosis: 5 mm high, bell-shaped, jelly moderately thick. With interradial gonads; 4 radial canals; 4 perradial marginal tentacles; unbranched oral tentacles; no ocelli.

Previous recorded distribution: All tropical and subtropical waters. Rare in Mississippi waters. Six specimens collected at station 74 on 27 March 1968, 2 specimens collected at station 73 on 10 December 1968, and 6 additional specimens collected at station 74 on 30 April 1969.

Family 4. Bougainvilliidae: Anthomedusae with simple tubular mouth with branched or unbranched oral tentacles; with 4 radial canals; marginal tentacles solitary or grouped in multiple marginal bulbs; may possess ocelli. Four representative species occur in Mississippi waters:

Nemopsis bachei L. Agassiz 1849 (Figure 9)

Bougainvillia carolinensis (McCrady 1857) (Figure 10)

Bougainvillia frondosa Mayer 1900 (Figure 11)

Lizia gracilis (Mayer 1900) (Figure 12).

Diagnosis: *Nemopsis bachei*. 10–15 mm high, globular, jelly moderately thick, with short manubrium; 4 radial

canals; repeatedly branched oral tentacles; marginal tentacles clustered in 4 groups of 15–20 (median pair of clavate tentacles in each group); 4 lobes of stomach extending along radial canals from which append the 4 ribbon like gonads.

Previous recorded distribution: Atlantic coast of United States, northern Gulf of Mexico, Holland. Extremely abundant in Mississippi waters during fall and winter.

Diagnosis: *Bougainvillia carolinensis*. 4–5 mm high, globular, jelly thick. With long slender manubrium; dichotomously branched oral tentacles; 4 radial canals; interradial gonads; 4 groups of 8 or 9 marginal tentacles. Tentacle bulbs contain ocelli.

Previous recorded distribution: Atlantic coast of United States, Gulf of Guinea. Occasionally abundant in Mississippi waters and occurs during all but winter months.

Diagnosis: *Bougainvillia frondosa*. 2–3 mm high, bell-shaped, jelly moderately thick. With 8 adradial gonads; 4 pairs of perradial marginal tentacles; oral tentacles branched dichotomously; no ocelli.

Previous recorded distribution: Florida. Rare in Mississippi waters. One specimen collected at station 71 on 19 June 1968.

Diagnosis: *Lizia gracilis*. 3 mm high, bell-shaped with vague apical projection, jelly moderately thick. With short manubrium; 4 perradial and 4 interradial oral tentacles; 8 marginal tentacles arranged in similar fashion; no ocelli.

Previous recorded distribution: Florida, Sunda Strait. Collected twice in Mississippi waters. Three specimens collected 27 March 1968 at station 74; and 2 specimens 20 May 1968 at station 71.

Family 5. Pandeidae: Anthomedusae with large apedunculate stomach; simple or lipped mouth; 4 radial canals; gonads on stomach walls; 2–8 hollow marginal tentacles. Ocelli present or absent. One representative in Mississippi waters:

Amphinema dinema (Péron & Lesueur 1809)

(Figure 13)

Diagnosis: 5–6 mm high, including prominent apical projection, width greater than 1/2 height; 4 adradial gonads attached to cruciform stomach; 4 radial canals; 2 long major tentacles; 2 bulbous alternate tentacles; numerous marginal warts; no ocelli.

Previous recorded distribution: Western Europe, entire Atlantic coast of United States, India, Australia. Common in offshore waters of Mississippi where it apparently occurs year round.

Order 2. Leptomedusae/Thecata: Hydromedusae with discoidal or hemispherical bell; gonads on radial canals. Sense organs, if present, cordyli or marginal vesicles. With or without ocelli.

Family 1. Laodiceidae: Leptomedusae with marginal cordyli. One representative in Mississippi waters:

Laodicea undulata (Forbes & Goodsir 1853)

(Figure 14).

Diagnosis: Large (ca. 30 mm), flatter than a hemisphere. With 4 sinuous gonads appended from the 4 radial canals; apedunculate stomach; 400–600 tentacles about 1/4 of which possess ocelli; a cirrus or cordylus between successive tentacles.

Previous recorded distribution: Entire east and west coasts of the Atlantic Ocean, Mediterranean Sea. A total of 35 specimens were collected from stations 71, 72 and 73 during two consecutive cruises, 24 through 26 September 1968 and 9 and 10 October 1968.

Family 2. Campanulariidae: Leptomedusae with small apedunculate stomachs; typically with 4 radial canals; gonads completely surrounding radial canals and separated from stomach; numerous closed marginal vesicles; no ocelli. Two representatives of the family occur in Mississippi waters:

Phialidium languidum (A. Agassiz 1862) (Figure 15)
Obelia sp. (Figure 16).

Diagnosis: *Phialidium languidum*. Campanulariidae with normal velum, 10–20 mm in diameter, bell flatter than a hemisphere, jelly thin. With about 32 hollow marginal tentacles; about 64 marginal vesicles; ovate gonads on each of 4 radial canals near bell margin.

Previous recorded distribution: Atlantic coast of United States. A total of 21 specimens were collected on 13 May 1968 at stations 57, 58 and 63. One specimen collected at station 70 on 18 May 1968, and another from that station on 30 July 1968.

Diagnosis: *Obelia* sp. Campanulariidae, 1–2 mm in diameter, with an extremely thin discoidal bell. With short stomach; 4 sac-like gonads near middle of each of 4 radial canals; numerous solid tentacles; 8 marginal vesicles. This genus was established by Péron & Lesueur in 1809.

Although the medusae are fairly common in all seas, no satisfactory means has been devised to specifically distinguish them. A total of 27 specimens of *Obelia* were collected during the following months at the corresponding sampling sites: May 1968, stations 63 and 68; June 1968, station 37; August 1968, station 32; September 1968, station 55; July 1970, station 5; September 1970, station 6; November 1970, station 5; and January 1971, station 69.

Family 3. Eirenidae: Leptomedusae with short pedunculate stomach; 4–6 radial canals; gonads surrounding radial canals; hollow marginal tentacles; closed marginal vesicles; no ocelli. With or without marginal cirri. Only the nominate genus occurs in Mississippi waters and is represented by two species:

Eirene pyramidalis (L. Agassiz 1862) (Figure 17)

Eirene viridula (Péron & Lesueur 1809) (Figure 18).

Diagnosis: *Eirene pyramidalis*. Eirenidae lacking lateral cirri, 30–40 mm wide, flatter than a hemisphere, jelly thick. With peduncle almost as wide as bell; linear gonads appended from distal end of each of 4 radial canals. The 100 or so marginal tentacles are similar, marginal vesicles of about same number as tentacles. Stomach small, lips much folded.

Previous recorded distribution: Bahamas; Florida; Jamaica; Beaufort, North Carolina. One hundred twenty-four specimens were collected during the following months at the corresponding stations: May 1968, station 69; September 1968, stations 71 and 73; October 1968, stations 70, 71 and 73.

Diagnosis: *Eirene viridula*. Eirenidae lacking lateral cirri, 20–30 mm wide, hemispherical, jelly thick. With long slender peduncle; linear gonads appended from distal end

of each of 4 radial canals; about 60 dissimilar marginal tentacles; marginal vesicles about as numerous as tentacles; small stomach with 4 pointed, much folded lips.

Previous recorded distribution: Northwestern Europe, Mediterranean Sea, Africa, Ceylon. One specimen of *E. viridula* was collected at station 68 on 6 May 1968 and a second one from station 70 on 18 June 1968.

Family 4. Eutimidae: Leptomedusae with short pedunculate stomach; 4 radial canals, from which append longitudinally divided gonads; hollow marginal tentacles; no marginal cirri; 8 closed marginal vesicles; no ocelli. With or without lateral cirri. Only the nominate genus occurs in Mississippi waters and is represented by two species:

Eutima variabilis McCrady 1857 (Figure 19)

Eutima mira McCrady 1857 (Figure 20).

Diagnosis: *Eutima variabilis*. About 30 mm wide, about 10 mm high; bell lens-like, jelly moderately thick. Peduncle twice bell diameter. With 8 gonads, 4 on peduncle, 4 on radial canals; 16 long marginal tentacles; lateral cirri present; marginal warts between tentacles; usually 8 closed marginal vesicles.

Previous recorded distribution: Atlantic coast of United States. A total of 18 specimens were collected on the following dates at the corresponding stations: March 1968, station 70; May 1968, stations 54 and 70; June 1968, station 72 and station 7; July 1968, stations 37 and 70; August 1968, station 4; and September 1970, station 7.

Diagnosis: *Eutima mira*. 30 mm diameter, bell lens-like, jelly thick. With long peduncle supporting short stomach; 8 gonads, 4 on peduncle, 4 on radial canals; 4 long tentacles; numerous marginal warts; 8 closed marginal vesicles.

Previous recorded distribution: Atlantic coast of United States. Two specimens collected at station 56 on 17 April 1968, 11 additional specimens collected at station 69 on 14 August 1968.

Order 3. Trachymedusae: Hydromedusae with umbrella margin entire and not lobate; gonads typically confined to radial canals; solid marginal tentacles, or both solid and hollow tentacles; marginal sensory clubs.

Family 1. Geryonidae: Trachymedusae with pedunculate stomach; 4 or 6 radial canals; centripetal canals present; phyllose gonads on radial canals; hollow and solid marginal tentacles. Two representatives of the family occur in Mississippi waters:

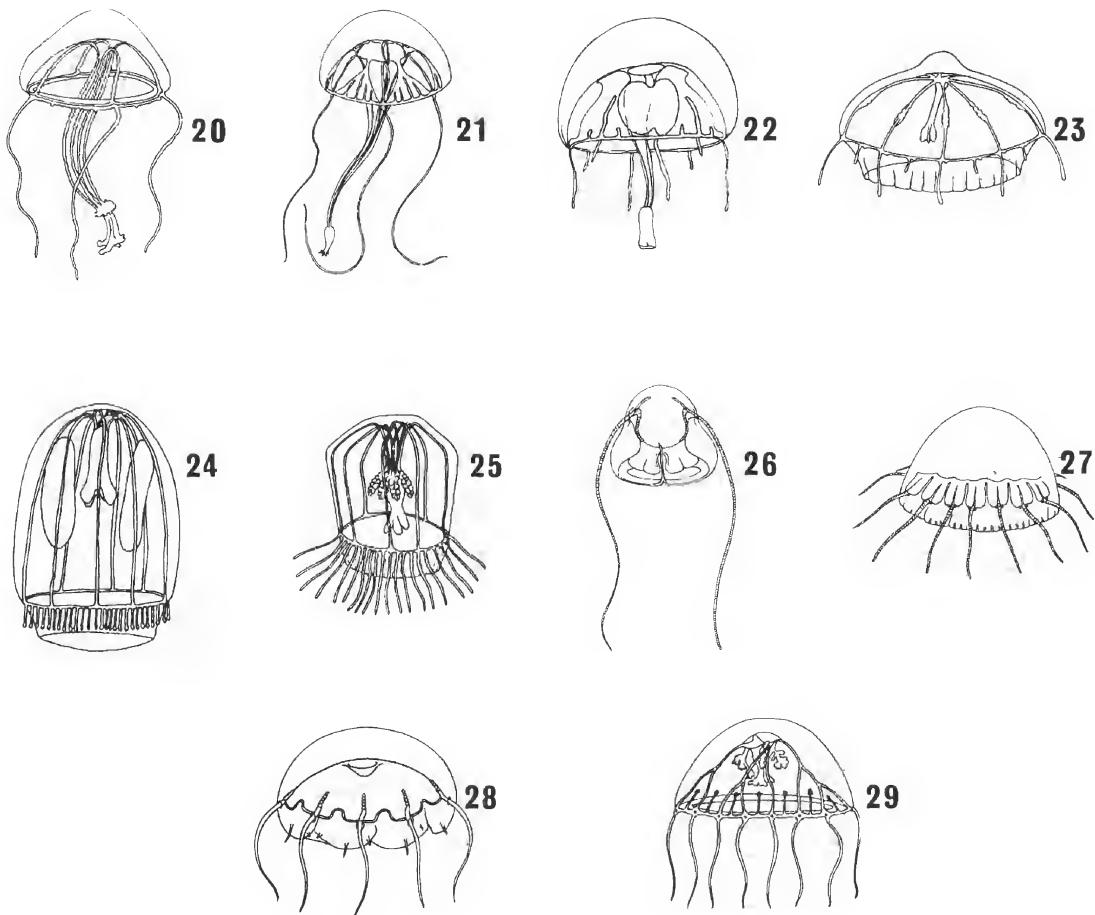
Geryonia proboscidalis (Forskål 1775) (Figure 21)

Liriope tetraphylla (Chamisso & Eysenhardt 1821) (Figure 22)

Diagnosis: *Geryonia proboscidalis*. Large 35–80 mm, hemispherical, jelly thick. With small stomach on long peduncle; 6 lips; 6 radial canals; centripetal canals between radial canals; 6 phylloid gonads; 6 hollow periradial marginal tentacles; 6 solid interradial marginal tentacles; 12 statocysts.

Previous recorded distribution: Worldwide in warm seas. One mature specimen was collected on 10 April 1968 at station 67.

Diagnosis: *Liriope tetraphylla*. 10–30 mm wide, hemispherical, thick-walled. With 4 phylloid gonads on each of 4 radial canals; interradial centripetal canals; 4 hollow periradial tentacles; 4 solid interradial tentacles; 8 statocysts.



Figures 20–29. 20. *Eutima mira* McCrady 1857. 21. *Geryonia proboscidialis* (Forskål 1775). 22. *Liriope tetraphylla* (Chamisso & Eysenhardt 1821). 23. *Rhopalonema velatum* Gegenbaur 1856. 24. *Persa incolorata* McCrady 1857. 25. *Aglaura hemistoma* Péron & Lesueur 1809. 26. *Solmundella bidentaculata* (Quoy & Gaimard 1833). 27. *Cunina peregrina* Bigelow 1909. 28. *Cunina octonaria* McCrady 1857. 29. *Proboscidactyla ornata* (McCrady 1857).

Previous recorded distribution: Worldwide in warm seas. Most abundant medusa in Mississippi waters. Occurs in virtually all high-salinity, high-temperature water masses.

Family 2. Rhopalonematidae: Trachymedusae with stomach with or without peduncle; usually 8 radial canals; no centripetal canals; globular pendent or linear gonads restricted to radial canals; 8 to many similar or dissimilar marginal tentacles; marginal clubs. Three representative genera occur in Mississippi waters:

Rhopalonema velatum Gegenbaur 1856 (Figure 23)

Persa incolorata McCrady 1857 (Figure 24)

Aglaura hemistoma Péron & Lesueur 1809 (Figure 25).

Diagnosis: *Rhopalonema velatum*. Hemispherical bell, 8–10 mm inclusive of apical prominence. With apedunculate stomach, ovate gonads at midpoint of 8 radial canals;

2 kinds of marginal tentacles; interradial and adradial cirri; 16 enclosed statocysts; broad curtainlike velum.

Previous recorded distribution: Worldwide in all warm seas. Twenty-eight specimens were collected during the following months at the corresponding offshore stations: June 1968, station 69; October 1968, station 74; December 1968, stations 71, 72, 73 and 74; January 1969, stations 73 and 74; April 1969, station 74.

Diagnosis: *Persa incolorata*. 2–3 mm high, distinctly bell-shaped, jelly thin. With tubular stomach on short peduncle; 8 radial canals; 2 ovate gonads near middle of 2 opposite radial canals; about 48 marginal tentacles; 8 statocysts.

Previous recorded distribution: Mediterranean Sea; tropical and southern Atlantic; southeast Australia; Beaufort, North Carolina. Common in Mississippi waters where it

occurs year-round.

Diagnosis: *Aglaura hemistoma*. About 5 mm high, thin-walled, somewhat prismatic. With rather long peduncle; short stomach; mouth with 4 small simple lips; 8 oval gonads on elongate peduncle; 8 statocysts; numerous marginal tentacles.

Previous recorded distribution: Worldwide in warm seas. Common in offshore waters of Mississippi, where it occurs year-round.

Order 4. Narcomedusae: Hydromedusae with lobate bell margins; gonads confined to stomach; no radial canals; 2-8 primary perradial tentacles arising aborally from the exumbrella. Secondary tentacles may arise from the bell margin. Sense organs are free sensory clubs.

Family 1. Aeginidae: Narcomedusae with interradial stomach pouches; primary perradial tentacles leaving umbrella between marginal pouches. With or without secondary tentacles arising from bell margin; with or without otoporpae. One representative of the family occurs in Mississippi waters:

Solmundella bitentaculata (Quoy & Gaimard 1833) (Figure 26).

Diagnosis: Aeginidae about 5 mm wide, higher than wide, jelly thick. With no peripheral canal system; 2 primary tentacles; no secondary tentacles; 8-32 statocysts.

Previous recorded distribution: Widely distributed in all seas; known to occur from Florida to Beaufort, North Carolina in United States. This medusa is fairly common year-round in offshore Mississippi waters.

Family 2. Cuninidae: Narcomedusae with undivided per-radial stomach pouches with or without peripheral canal system; with tentacles leaving umbrella opposite center of each stomach pouch, equal in number to that of pouches; pouches not extending beyond points of origin of tentacles. Without secondary tentacles on umbrella margin; with or without otoporpae. The nominate genus is represented in Mississippi waters by two species:

Cunina peregrina Bigelow 1909 (Figure 27)

Cunina octonaria McCrady 1857 (Figure 28).

Diagnosis: *Cunina peregrina*. 10-14 mm wide, highly domed, jelly thick. With no peduncle; 8-14 (usually 12) well-rounded stomach pouches; broad marginal lappets, each with 4-10 statocysts; with narrow otoporpae; no peripheral canals.

Previous recorded distribution: Tropical Pacific and Atlantic Oceans; western region of Indian Ocean; recently found in Beaufort, North Carolina. Three specimens collected at station 73 on 26 March 1968.

Diagnosis: *Cunina octonaria*. 5-7 mm wide, flatter than a hemisphere, jelly thick. With 8 square stomach pouches; no peduncle; marginal lappets with 2-5 statocysts each; small otoporpae; no peripheral canals.

Previous recorded distribution: Worldwide in warm seas. One hundred forty-two specimens were collected in Mississippi waters during the following months at the corresponding stations; September 1968, stations 71, 72, 73 and 74; October 1968, stations 70, 71, 73 and 74; November 1968, station 73; January 1969, station 70; April 1969, station 74.

Order 5. Limnomedusae: Hydromedusae with gonads either only on stomach, or both on stomach and extending a short distance along radial canal, or only on radial canals; with or without statocysts; statocysts in form of enclosed sensory clubs; hollow marginal tentacles.

Family 1. Proboscidactylidae: Limnomedusae without statocysts; stomach usually with 4, 6 or more radial lobes along proximal portions of radial canals; gonads surrounding stomach and appending somewhat onto radial canals; with branched radial canals; no ocelli. One representative of the family occurs in Mississippi waters:

Proboscidactyla ornata (McCrady 1857) (Figure 29).

Diagnosis: 9 mm high, somewhat higher than a hemisphere, thick jelly. With 4-lobed stomach; mouth with 4 crenated lips; 4 primary radial canals; 16-20 terminal canal branches with corresponding number of tentacles; no ring canal.

Previous recorded distribution: Circumglobal in warm coastal waters. A total of 45 specimens were collected in Mississippi waters during the following months at the corresponding sampling sites: May 1968, station 71; June 1968, stations 72, 73 and 74; September 1968, stations 72 and 74; October 1968, stations 72 and 73; November 1968, station 71; December 1968, stations 72 and 73; January 1969, station 70; April 1969, station 74.

Order 6. Siphonophorae: Six species of siphonophores were collected in Mississippi Sound during the first year of the study period. An additional 19 species were collected from stations located south of Mississippi Sound. The occurrence of all these species is recorded in Tables 1 and 2. The occurrence of siphonophores in Mississippi Sound was reported in an earlier publication (Phillips and Burke 1970). Accounts of the species known to occur in the open waters south of Mississippi Sound are given by Phillips (1971, unpublished MS).

SCYPHOZOA

The scyphozoan medusae collected in Mississippi waters during the study period represented four orders, perhaps nine families and ten species. Areal and seasonal distributions of all species of Scyphozoa collected in Mississippi are indicated in Tables 1 and 2 respectively. The salinities and temperatures with which these medusae were associated are given in Table 3. Accounts, diagnoses, and previous known distributions are given in the following section. The diagnoses and distributions are those of Russell (1970) and Mayer (1910).

CLASS SCYPHOZOA: Polyp small, if present; gastric ridges present. Medusa almost always present but without a velum.

Order 1. Coronatae: Scyphomedusae with umbrella with coronal groove surrounding a central disk and with peripheral pedalia corresponding to numbers of solid marginal tentacles and marginal sense organs, and with marginal lappets. The mouth is simple, short and provided with simple lips.

Family 1. Nausithoidae: Coronate scyphomedusae with 4 perradial and 4 interradial marginal sense organs; with 8 adradial marginal sense organs; with 8 adradial marginal

TABLE 3.

Maximum and minimum values of salinities and temperatures at which various species of scyphomedusae were collected in Mississippi waters, 1968-1971.

Species	Salinity (ppt)	Temperature (°C)
<i>Aurelia aurita</i>	29.2-31.6	24.1-25.8
<i>Chiropsalmus quadrumanus</i>	18.2-34.0	15.0-30.1
<i>Chrysaora quinquecirrha</i>	10.6-31.3	20.9-32.0
<i>Cyanea capillata</i>	23.2-29.6	14.0-16.0
<i>Nausithoë punctata</i>	35.3	18.8
<i>Pelagia noctiluca</i>	32.0-33.9	17.8-23.6
<i>Stomolophus meleagris</i>	19.4-25.7	17.1-33.0

tentacles; without sac-like pouches on subumbrella; with 4 or 8 gonads. There is one representative of the family in Mississippi waters:

Nausithoë punctata Kölle 1853.

Diagnosis: Nausithoidae about 10 mm wide, umbrella discoidal, jelly thick. Central disk thick, raised, and finely punctate. Eight adradial gonads; 8 marginal sense organs, 4 radial, 4 perradial; alternating with 8 short adradial tentacles. The 4 lips are simple; the mouth is central and cruciform. Bell translucent; gonads reddish brown.

Previous recorded distribution: Mediterranean Sea, Atlantic, Pacific and Indian Oceans, and in all tropical or warm seas. One such specimen was collected at station 69 in November 1970.

Family 2. *Paraphyllinidae*: Coronate scyphomedusae with 4 perradial marginal sense organs and 4 or more marginal tentacles in groups of 3 between adjacent marginal sense organs. One specimen of *Paraphyllina* was collected in 1968 from station 73. The specimen was never satisfactorily identified and was lost in the August 1969 hurricane.

Order 2. *Semaeostomeae*: Scyphomedusae without coronal furrow and without pedalia, with hollow marginal tentacles, interradial gastric septa lacking; with radial septa in gastrovascular sinus or without gastrovascular canal system; with 4 simple oral arms with crenulated lips.

Family 1. *Pelagiidae*: Semaeostome medusae with gastrovascular sinus divided by radial septa into separate simple rhopalar and tentacular pouches. Tentacles arise along the margin of the bell. The family is represented in Mississippi waters by two species:

Pelagia noctiluca Forskål 1775

Chrysaora quinquecirrha (Desor 1848)

Diagnosis: *Pelagia noctiluca*. Pelagiidae about 50 mm in diameter, somewhat dome-shaped. Sides of bell straight and sloping, apex flat. Eight adradial tentacles alternate with 8 rhopalia, bell thus with 16 marginal lappets. Stomach with 16 radiating pouches in the rhopalar and tentacular radii. No ring canal.

Previous recorded distribution: Circumglobal in all warm and temperate waters. *Pelagia* is an oceanic form and occurs in Mississippi waters only erratically. Moribund specimens were collected in Mississippi Sound in March 1968. Adult medusae and juveniles ranging from 10 mm in bell diameter

were fairly common in offshore waters during spring and summer. Four hundred nineteen specimens were collected during the study period.

Diagnosis: *Chrysaora quinquecirrha*. Pelagiidae 60-190 mm in diameter, with 8 marginal sense organs, 24-40 marginal tentacles, and 32-48 or more marginal lappets. Bell variously pigmented, 16 radiating russet stripes with central pigmented spot on apex most common. Gastrovascular cavity divided as in *Pelagia*.

Previous recorded distribution: Atlantic coast of America from New England to tropics. *Chrysaora quinquecirrha* is the most abundant scyphomedusa in Mississippi waters. This form is tolerant of wide variations of environment and occurs in Mississippi Sound and the adjacent Gulf from April through September inclusive.

Family 2. *Cyaneidae*: Semaeostome medusae with gastrovascular sinus divided by radial septa into branched rhopalar and tentacular pouches. Tentacles arise from subumbrella surface some distance from the umbrella margin. The family is represented in Mississippi waters by one species:

Cyanea capillata (L).

Diagnosis: Cyaneidae 60-150 mm in diameter, rather flat. Eight deep adradial tentacular clefts, 8 shallow perradial and interradial rhopalar clefts. Tentacles arranged in 8 crescentic adradial clusters, each cluster with multiple rows of tentacles. Tentacle numbers vary but several hundred present in fully developed specimens. Gastrovascular radial pouches much ramified. Oral arms curtainous and about as long as bell diameter. Color of live Mississippi specimens usually deep russet.

Previous recorded distribution: Boreally circumpolar, possibly cosmopolitan as systematics of the group is vague. *Cyanea* is not common in Mississippi waters. About 200 specimens were collected during the early springs of 1968, 1969 and 1970.

Family 3. *Ulmariidae*: Semaeostome medusae with gastrovascular system of unbranched and branched radial canals with varying degrees of anastomosis, producing a functional ring canal. Tentacles hollow, 4 interradial gonads. The 4 oral arms are much folded and curtainous. The family is represented in Mississippi waters by one species:

Aurelia aurita (L)

Diagnosis: Ulmaridae 90-400 mm in diameter, rather flat, exumbrella smooth. Margin with 8 broad lobes; very numerous small hollow marginal tentacles on exumbrella slightly above margin, 1-3 of which alternate with minute lappets. Four perradial and 4 interradial rhopalia; 4 interradial folded gonads in a crescentic or circular configuration; stomach with 4 interradial circular gastric pouches; 8 unbranched adradial canals, 4 branched perradial and 4 branched interradial canals, all communicating with a marginal ring canal. Four perradial oral arms about as long as bell radius. Basal portions of manubrium fused to form 4 subgenital pits with circular orifices. Live specimens translucent with pink radial canals, oral arms and gonads.

Previous recorded distribution: Generally distributed from boreal to tropical waters. *Aurelia* is a winter form in Mississippi and was fairly common during the winter of

1969-70 and again during the 1970-71 winter. Thousands of specimens flowed into Mississippi Sound during December 1966, then *Aurelia* was peculiarly absent from Mississippi waters until the winter of 1969.

Order 3. Rhizostomeae. Scyphomedusae lacking marginal tentacles, and with numerous mouths which are borne upon 8 adradial, fused oral arms arising from the center of the umbrella. The order is represented by two species in Mississippi waters:

Stomolophus meleagris (L. Agassiz 1862)

Rhopilema verrilli (Fewkes 1887).

Diagnosis: *Stomolophus meleagris*. Rhizostome medusae, 100-380 mm in diameter, hemispherical or globular with thick jelly. With a central mouth opening, with a well-developed, tube-like manubrium formed by the fusion of 8 primitive oral arms. Only the most distal portions of the oral arms are free and ramify extensively. With 8 pairs of scapules, and 4 separate invaginated gonads. The central gastrovascular cavity produces 16 radial canals which are freely connected through anastomosing vessels. Eight marginal sense organs. Frequently highly pigmented. Extremely young specimens are flatter than a hemisphere.

Stomolophus, almost always present in Mississippi Sound in varying numbers, was most abundant during winters. Specimens were collected which ranged from 3.0 mm to 380 mm, suggesting that a few medusae may survive for periods of time in excess of one year.

Previous recorded distribution: Atlantic coasts of America from Chesapeake Bay to Tortugas, Florida; Gulf of Mexico; Atlantic coast of South America.

Diagnosis: *Rhopilema verrilli*. Rhizostome medusae 60-600 mm in diameter, flatter than a hemisphere; with 8 marginal sense organs; 64 marginal lappets, 6 large oval lappets in each octant of the margin together with 2 small lappets adjacent to each sense organ. The 16 radial canals anastomose freely. The arm-disk is cruciform and about half as wide as the bell. The 8 short lower oral arms, which arise from the arm-disk are about as long as the bell radius and are Y-shaped in cross section. The oral arms branch sparingly and bear numerous mouths on their lower and inner sides, finger-like appendages borne terminally; a pair of lateral scapules arise from the outer side of each of the oral arms. The bells of specimens in Mississippi are translucent; gonads, mouth and radial canals are yellowish.

Previous recorded distribution: Atlantic coasts of United States and Gulf of Mexico. Most of the specimens collected in Mississippi waters were found stranded along the swash

lines of the several barrier islands. Eleven specimens were collected in this fashion in March, April and May 1968 and in March, May and December 1970.

Order 4. Cubomedusae: Scyphomedusae with 4 per-radial, knob-shaped marginal sense organs located in niches upon the sides of bell; with 4 interradial tentacles or groups of tentacles. Four wide perradial sacs extend outward from stomach into the interstitial space of the bell. These sacs are partially separated from each other by 4 interradial septa. There are 8 leaf-shaped gonads. The subumbrella forms an annular diaphragm (velarium) which partially closes the opening of the bell cavity. The proximal parts of the tentacles are developed into tough spatula-like structures (pedalia). The mouth is cruciform and simple. Like the Coronatae, this order has interradial septa in the stomach. Two representatives of this order occur in Mississippi waters:

Chiropsalmus quadrumanus (Müller 1859)

Tamoya haplonema Müller 1859.

Diagnosis: *Chiropsalmus quadrumanus*. Cubomedusae, 28-130 mm high, dome-shaped, with 4 prominent pedalia bearing 7-9 hollow tentacles each; with 4 sense organs within 4 covered niches upon the bell some distance above the bell margin. Elaborate ectodermal eyes upon sense clubs. Velarium wide with branched pouches communicating with stomach. Stomach globular, mouth simple with 4 triangular lips; 4 wide perradial pouches extend from stomach into bell wall, from each pouch append 2 hollow sacs which extend well into the cavity of the bell.

Previous recorded distribution: Atlantic Ocean from Brazil to Beaufort, North Carolina; Sumatra; Australia; West Africa; the Indian Ocean and the Gulf of Mexico. *Chiropsalmus* appeared in Mississippi waters during the late summer or winter of each of the three years of the study period, and was occasionally locally abundant. The ecology of this animal in Mississippi waters was discussed by Phillips and Burke (1970).

Tamoya haplonema, a species closely related to *Chiropsalmus*, was collected in October 1968 at station 74. The two specimens were lost to the August 1969 hurricane; however, a specimen of *Tamoya* collected in 1959 by a shrimp boat off the coast of Alabama remains extant in the Gulf Coast Research Laboratory Museum, Ocean Springs, Mississippi.

Tamoya apparently occurs in all warm seas of the world and may be readily distinguished from *Chiropsalmus* in that the pedalia of the former are unbranched and bear but a single tentacle.

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Gulf Research Reports

Volume 5 | Issue 1

January 1975

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DOI: 10.18785/grr.0501.05

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Recommended Citation

Perry, H. M. 1975. The Blue Crab Fishery in Mississippi. *Gulf Research Reports* 5 (1): 39-57.
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THE BLUE CRAB FISHERY IN MISSISSIPPI¹

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ABSTRACT Analysis of 670 trawl, seine and marsh net samples collected from July 1971 through June 1973 provided data on the distribution and abundance of blue crabs in Mississippi Sound. Highest average catches were associated with salinities between 5.0 and 15.0 ppt (parts per thousand) and temperatures between 20.0 and 25.0°C.

Young crabs congregated in dredged navigational channels and in the marshes that fringe the bays and coastline. Maximum numbers were captured over soft mud bottoms.

Peak numbers of zoeae occurred in the summer and fall. Megalopae were collected in all months. Early crab stages appeared throughout the year. Width-frequency distributions suggested rapid growth.

Crabs tagged and released in Lake Borgne, La. during the fall of 1971 moved into Mississippi Sound in the vicinity of Cat Island to overwinter. Recoveries of crabs released in the St. Louis Bay, Biloxi Bay and Pascagoula River estuarine systems indicated little movement between estuaries during the spring and summer.

Identified parasites included a new microphallid trematode.

Commercial landings of blue crabs averaged 1,712,000 pounds for the 20-year period 1953-1972. Catch per unit of effort (pounds/pot day) was low during the spring and fall, peaking in the summer. Rises in the catch per unit of effort closely followed the migration of female crabs into Mississippi Sound.

INTRODUCTION

The blue crab, *Callinectes sapidus* and its smaller congener, *Callinectes similis* are abundant in Mississippi coastal waters. Blue crab landings in Mississippi amount to over one million pounds annually, and the fishery ranks third in value of all food fisheries in the Gulf of Mexico. In addition, the blue crab supports an important recreational fishery in Mississippi. Herring and Christmas (1974) estimated that sport crabbers land about 50,000 pounds annually from Mississippi waters.

Extensive investigations on the biology of the blue crab in Chesapeake Bay have been conducted by Hay (1905), Churchill (1919) and Van Engel (1958). Prior to 1952, literature concerning the biology of this species in Gulf of Mexico waters remained scarce. However, since that time, northern Gulf studies on the blue crab include those of Daugherty (1952), Darnell (1959), Menzel (1964), More (1969), Holland et al. (1971), Jaworski (1972) and Adkins (1972b). In addition, the general works of Gunter (1950), Hedgpeth (1950), Reid (1955, 1956), Breuer (1957, 1962), Simmons (1957), Chambers and Sparks (1959), Hoese and Jones (1963) and King (1971) contributed much information on this species in coastal Gulf waters. Prior to the present study, a detailed investigation of blue crab populations in Mississippi Sound and adjacent waters had not been undertaken.

Bibliographies dealing with the blue crab life history, biology and fishery have been published by Cronin et al. (1957) and Tagatz and Hall (1971).

AREA DESCRIPTION

Mississippi Sound is a shallow estuarine area bounded by Mobile Bay on the east and by Lake Borgne on the west, and loosely separated from the Gulf of Mexico by a chain of barrier islands. Fresh water enters the Sound from the Pearl River, St. Louis Bay, Biloxi Bay and Pascagoula River watershed systems. Low-salinity waters from Mobile Bay to the east and Lake Borgne to the west also enter the Sound. The barrier islands consist primarily of beaches and dunes, with the beaches forming both sides of the islands and small swamps and ponds located in the interior (Shepard 1960). The intertidal area is almost entirely sand which gradually grades into mud away from shore. The beaches along much of the Mississippi mainland are man-made, having been pumped from adjacent offshore water bottoms. Little vegetation is found along these beaches as they are "maintained" for public recreational use. Soft mud sediments characterize the bottom of most of the Sound, except in areas near the barrier islands. Coastal bays are shallow with soft mud sediments. A more detailed description of Mississippi Sound has been reported by Christmas (1973).

Submerged vegetation near the mainland is dominated by *Ruppia maritima*. Beds of *Diplanthera wrightii*, *Cymodocea manatorum* and *Thalassia testudinum* are located just north of the barrier islands (Eleuterius 1973b).

Ninety-four percent of the coastal mainland marsh is dominated by *Juncus roemerianus*. Eleuterius (1973a) provided details on the composition and zonation of Mississippi marshes.

Sampling Locations

Fixed stations representing blue crab habitats were established in the St. Louis Bay, Biloxi Bay and Pascagoula River estuaries. Sampling was concentrated in the Biloxi Bay

¹This work was conducted in cooperation with the Department of Commerce, NOAA, National Marine Fisheries Service, under Public Law 88-309, Project 2-123-R.

estuary. The division of Mississippi Sound into salinity zones as defined by Christmas and Eleuterius (1973) was used in establishing sampling locations (zones were arbitrarily based on average bottom salinity and geographic location). Zones were numbered from fresh water, zone 1, through the salinity gradient to saline water, zone 5 (Figure 1). Sampling sites were located in zones 2 through 5. Station locations by gear type are shown in Figure 2.

MATERIALS AND METHODS

Field and Laboratory Procedures

Simultaneous surface and bottom plankton samples were taken from July 1970 through December 1972 with Clarke-Bumpus samplers fitted with No. 3 mesh nets, towed at a constant speed for 10 minutes. Samples were preserved in the field in a 5% solution of formalin buffered with methenamine.

Settled volume of plankton was determined for each sample. Samples with settled volumes less than 5 ml were examined entirely. When volumes exceeded 5 ml, aliquots were taken with a Folsom plankton splitter.

Standard collecting gear for juvenile and adult crabs included a 16-foot otter trawl with 3/4-inch wing mesh and 1/4-inch tail mesh and a 50-foot (1/4-inch bar mesh) bag seine. Trawls were pulled for 10 minutes. Seines were set by hand or from a skiff and were pulled at various distances from the shoreline depending upon the topography of the bottom.

A marsh net with a 1-mm mesh was used to determine the distribution of postlarval and small juvenile crabs. Routine sampling for postlarval, juvenile and adult blue crabs began in July 1971 after preliminary sampling had defined optimal habitats.

All trawl, seine and marsh net samples were iced in the field and brought to the laboratory for analysis. In the laboratory, carapace width, weight, sex, maturity stage and growth stage (hard, buster, soft, buckram) were recorded for each crab. Mature females were examined to determine ovarian state using the method described by Hard (1942). Each crab was checked for parasites and epizoans.

Temperature and salinity were measured with a Beckman salinometer (Model RS5-3) at deep-water trawl and plankton stations. At shallow-water stations a mercury thermometer and a refractometer (AO Model 10402) were used. Comparisons of results from salinometer and refractometer measurements showed no significant differences. Dissolved oxygen was measured at all stations with a portable oxygen meter (YSI Model 54).

Male and female blue crabs were tagged in November-December 1971 and May-July 1972. Crabs, obtained from commercial fishermen, were tagged and released in the area of capture. A yellow "spaghetti" tag bearing the initials GCRL, Ocean Springs and serially numbered, was strung on plastic coated leader wire and attached between the large lateral spines of the carapace. The leader wire was secured as a loop by pulling the ends through a brass ferrule and clamping. Carapace width and sex were recorded before the

crabs were released.

Preceding tagging in the fall of 1971, a press release was widely published, letters announcing the program were written to other Gulf of Mexico laboratories, and posters were placed at strategic points in processing plants, on public piers, at fishing camps, etc. Processing plants were visited regularly and individual crab fishermen were contacted to enlist their cooperation. Prior to the second release of crabs, in the late spring and summer of 1972, a notice was prepared for distribution to each commercial fisherman buying a license in Mississippi. Distribution of these notices was carried out by the Mississippi Marine Conservation Commission. No reward was offered for the return of tags.

A survey of the commercial catch was begun in July 1970 in the Biloxi Bay area. Data were collected on the size and sex composition of the commercial catch and on the areas of crabbing. Data on the catch per unit of effort and the number of days of crabbing were obtained from the records of commercial processing houses. Interviews were conducted with local fishermen.

LARVAL STUDIES

Callinectes sapidus spawns in coastal Gulf and estuarine waters from early spring through fall, and perhaps in winter, while *Callinectes similis* spawns in Gulf waters in all seasons. Although there is no clear evidence that *C. similis* larvae enter the Sound, the possibility of co-occurrence of the larvae in plankton samples cannot be overlooked. Since the task of separating the two species would be difficult and time consuming (Dr. C. G. Bookhout, personal communication), zoeae and megalopae were consequently identified to *Callinectes* spp.

When *Callinectes* megalopae appeared in plankton samples in January and February of 1971, samples were cultured and developed to early crab stages. All surviving crabs were identified as *C. sapidus*. Early crab stages of *C. similis* were collected in marsh net samples in the Sound. Plankton and nekton samples from offshore Mississippi waters also contained early crab stages of *C. similis* (sive Allison Perry). Early crab stages of *C. sapidus* were rarely collected in plankton samples from the Sound.

Seasonal Distribution of Larvae

Peak numbers of *Callinectes* zoeae were collected in August 1970, June, July, and September of 1971 and in June through August of 1972. Smaller numbers were collected in the spring and fall. The seasonal pattern of zoeal occurrence and abundance was coincident with the appearance of berried female blue crabs in coastal Gulf and estuarine waters. Spawning in the northern Gulf begins in early spring and continues through the fall, reaching a peak during the summer months (Darnell 1959, More 1969, Adkins 1972b). In addition to the spring, summer and fall spawning groups, Adkins noted a winter group of spawning females in the offshore waters of Louisiana. No such group has been observed in Mississippi Sound.

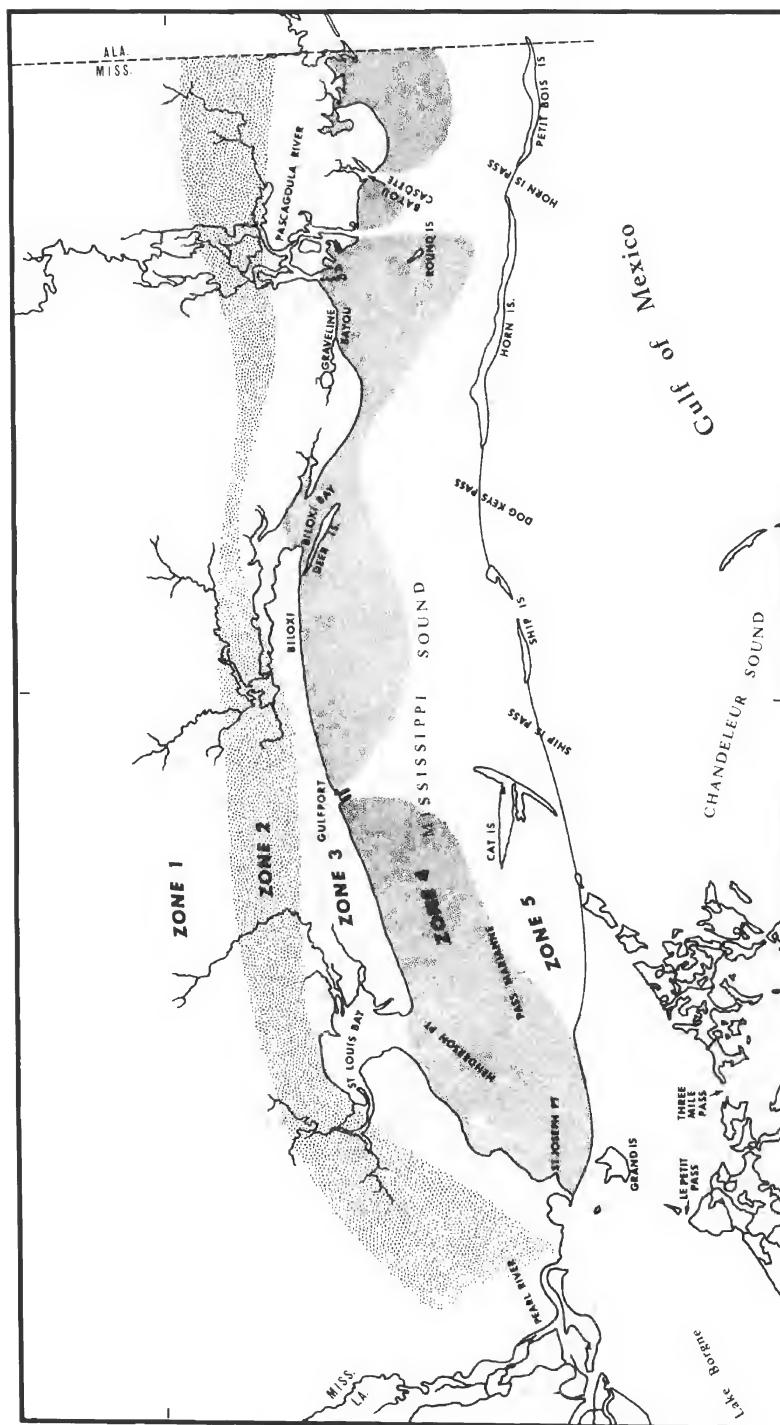


Figure 1. Salinity Zones 1-5, Mississippi Sound

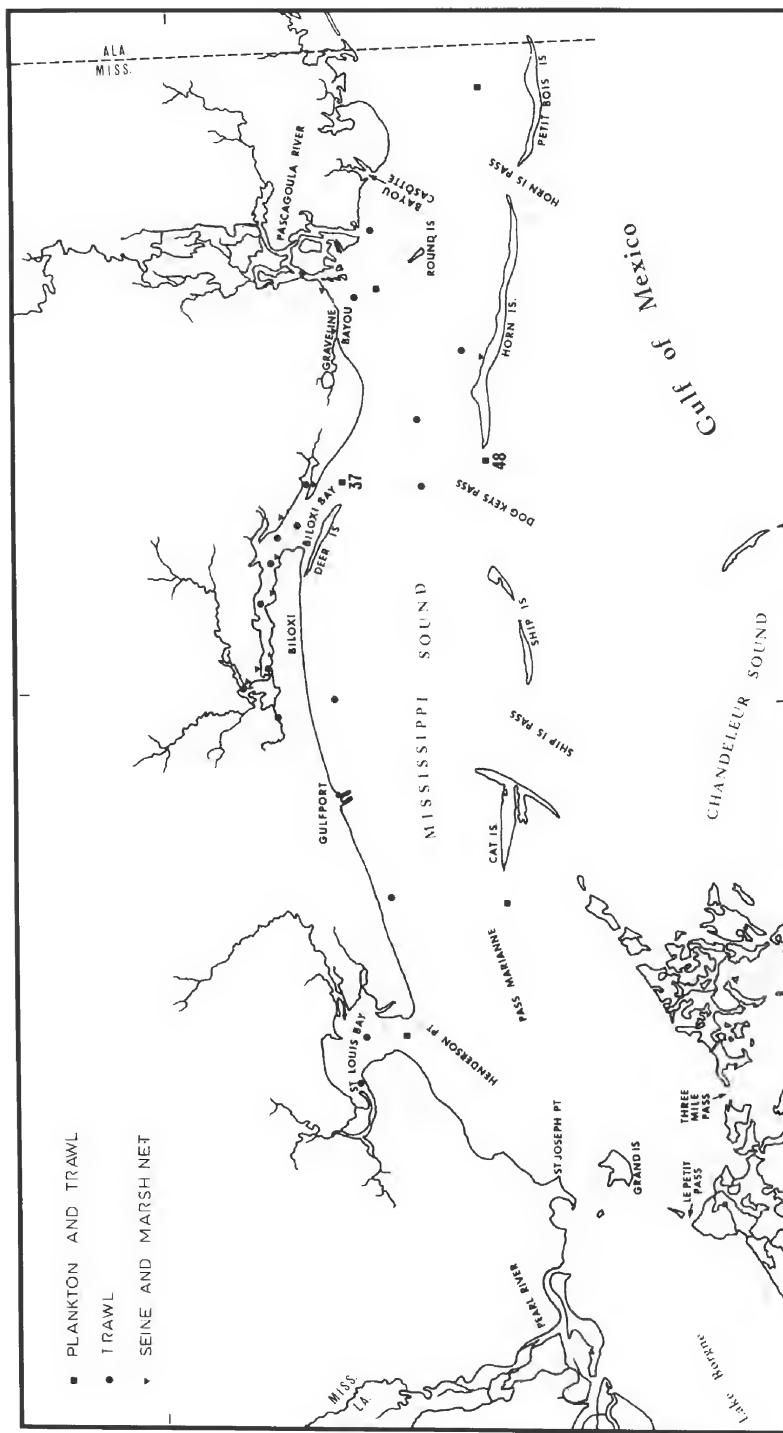


Figure 2. Location of stations.

Megalopae were collected in all seasons but were most abundant in samples collected in September 1970, February 1971 and August 1972. The origin of the winter peak of megalopae in Mississippi Sound is not known. More (1969) noted the occurrence of *Callinectes* megalopae in all months but December in Texas passes and Adkins (1972b) noted a February peak for megalopae in Louisiana. Costlow (1967) reported from laboratory studies that 50% of the megalopae held at 15.0°C in 35.0 ppt salinity survived 37–55 days before metamorphosis to early crab stages. This would allow for the overwintering of megalopae of *C. sapidus*.

Areal Distribution of Larvae

Peak numbers of zoeae were collected at station 48 in Dog Keys Pass, with numbers sharply reduced at the entrance to Biloxi Bay. Zoeae were virtually absent from the upper reaches of Biloxi Bay.

Megalopae were periodically numerous in the lower estuary, being particularly abundant in September 1970 both in Dog Keys Pass and at the entrance to Biloxi Bay and in August 1972 in Dog Keys Pass. When megalopae were abundant, they penetrated as far as the middle of Biloxi Bay. Megalopae were also collected (marsh net) along the edge of the marshes in zones 3 and 4.

Vertical Distribution

The total number of zoeae collected at the surface in Dog Keys Pass during 30 months was similar to that collected at the bottom. There was a general trend toward greater surface concentrations from July 1970 through May 1972. Beginning in June 1972 and continuing through the first sample in August 1972, zoeae were more numerous in bottom samples. It is evident that zoeae were transported via both surface and bottom currents.

Megalopae were most abundant in surface samples. Tagatz (1968a), however, found that in the area of St. Johns River, Florida, 96.0% of the *Callinectes* megalopae occurred in bottom collections.

Hydrography

Salinity, temperature and dissolved oxygen were measured when plankton samples were taken.

Temperature variations between surface and bottom samples showed maxima of 2.7°C in May 1971 and 2.5°C in March 1972 at stations 37 (10 feet) and 48 (30 feet), respectively. The highest temperature (31.3°C) was observed in August 1972 at station 37 at the surface. In general, bottom temperatures at station 48 were lower than surface temperatures with inversions occurring in July 1970, February, March and December of 1971 and in October and December of 1972. In February 1971 the bottom water was 1.3°C warmer than surface water. Bottom water was 0.2°C and 0.5°C warmer than surface water at station 37 in December 1970 and October 1971, respectively. The lowest temperature (10.5°C) was recorded in December 1972 at station 37 at the bottom.

Salinity was highly variable at the mouth of Biloxi Bay. Surface values ranged from a high of 29.1 ppt in November 1970 to a low of 2.0 ppt in May 1972. Vertical salinity gradients of 13.0 ppt were observed at this station in December 1971 and May 1972. Salinities in Dog Keys Pass were more constant, with the greatest fluctuation recorded during the winter of 1971–72. Surface salinities began to drop in December 1971 and continued through March 1972. Salinities of 13.0 ppt and 12.0 ppt were recorded in February and March, respectively. The highest salinity (34.1 ppt) was recorded at the bottom at station 48 in July 1971.

The dissolved oxygen concentration was adequate at all stations.

Discussion

Callinectes zoeae were infrequently present in sampling areas from November 1970 to April 1971 when water temperatures were below 17.0°C. Although water temperatures were somewhat warmer during the same period in 1971–1972, zoeae were still conspicuously absent from plankton samples. Areal distribution of zoeae was apparently limited by salinity. Although a few zoeae were collected in salinities below 20.0 ppt, survival over an extended period of time was not likely. Costlow and Bookhout (1959) indicated that zoeae rarely complete the first molt in salinities below 20.1 ppt. In general, *Callinectes* zoeae occurred under conditions favorable for larval growth as revealed by laboratory studies.

Callinectes megalopae were found at greater temperature and salinity extremes than zoeae. Some specimens were collected in salinities as low as 4.0 ppt, although most were found in salinities above 20.0 ppt. Megalopae were collected in February 1971 when the water temperature was 11.4°C.

Seasonal and areal distributions of zoeae and megalopae in the St. Louis Bay and Pascagoula River estuaries were in agreement with data collected for the Biloxi Bay estuary.

JUVENILE AND ADULT STUDIES

Hydrography

Figures 3 and 4 illustrate differences in surface and bottom temperatures and salinities at trawl stations in zones 2 through 5 from August 1971 through June 1973.

Temperature

Bottom temperatures at trawl stations averaged lower than surface values with few exceptions. The greatest average temperature difference between surface and bottom waters (2.4°C) was recorded in February 1973 in zone 2. Temperature maxima and minima occurred in zone 2 in August 1971 (33.0°C) and in zones 3, 4 and 5 in January 1973 (10.0°C), respectively. Temperature ranges in the following discussions refer to averages.

Surface temperatures in zone 2 varied from a low of 12.2°C in February 1972 to a high of 33.0°C in August 1971. Bottom temperatures averaged somewhat lower,

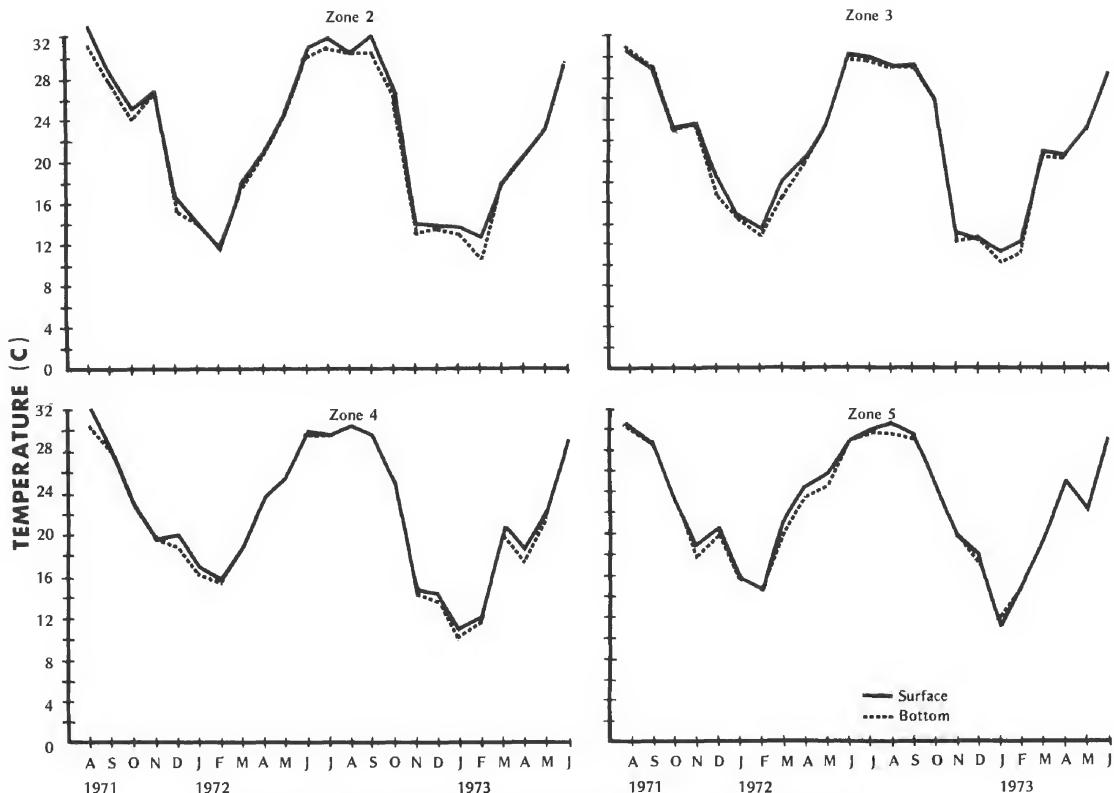


Figure 3. Average monthly surface and bottom temperatures, zones 2 through 5

ranging from 10.4°C (February 1973) to 31.1°C (August 1971).

Temperatures in zone 3 ranged from 11.1°C (January 1973) to 30.2°C (June 1972) at the surface and from 10.2°C (January 1973) to 30.5°C (August 1971) at the bottom.

Zone 4 surface readings varied from a low of 10.8°C recorded in January 1973 to a high of 32.0°C recorded in August 1971. Bottom readings ranged from a low of 10.0°C in January 1973 to a high of 30.6°C in August 1971.

Surface temperature extremes in zone 5 ranged from 10.8°C (January 1973) to 30.6°C (August 1972). Bottom temperatures averaged lowest in January 1973 (11.8°C) and highest in August 1971 (29.9°C).

Water temperatures followed a seasonal pattern with maxima in the summer months (June, July, August) and minima in January or February.

Temperatures in zones 2, 3 and 4 began to decline in December of 1971 and in November of 1972. Averages for November 1972 in these zones were considerably lower than averages in November of 1971. No significant difference in November temperatures was observed in zone 5.

Areal variations in temperature were slight. In general, the seasonal and areal temperature variations observed in

the present study were in close agreement with existing data as reported by Christmas, Gunter and Musgrave (1966) and Christmas and Eleuterius (1973).

Salinity

Bottom salinities at trawl stations always averaged higher or equaled surface values. Salinities were lowest in zones 2 and 3 and increased through zones 4 and 5.

Salinities at the surface in zone 2 averaged below 5.0 ppt in 16 of the 23 months. The highest reading (16.0 ppt) was recorded in October 1972. Vertical salinity gradients in this zone ranged from 0.0 ppt (September 1971, January–March 1972, May 1972, March–April 1973) to 10.3 ppt (December 1972). Bottom salinities averaged slightly higher, ranging from 0.0 ppt (September 1971, January–March 1972, May 1972, March 1973) to 17.0 ppt (October 1972). Salinities in zone 2 were fresh when river discharge was high. The presence of a salt-water wedge was periodically detected in this zone and was particularly evident in December 1972 when surface salinities averaged 3.7 ppt and bottom salinities averaged 14.0 ppt.

Salinities in zone 3 varied from 0.0 ppt (January 1972) to 21.0 ppt (September 1972) at the surface. Bottom

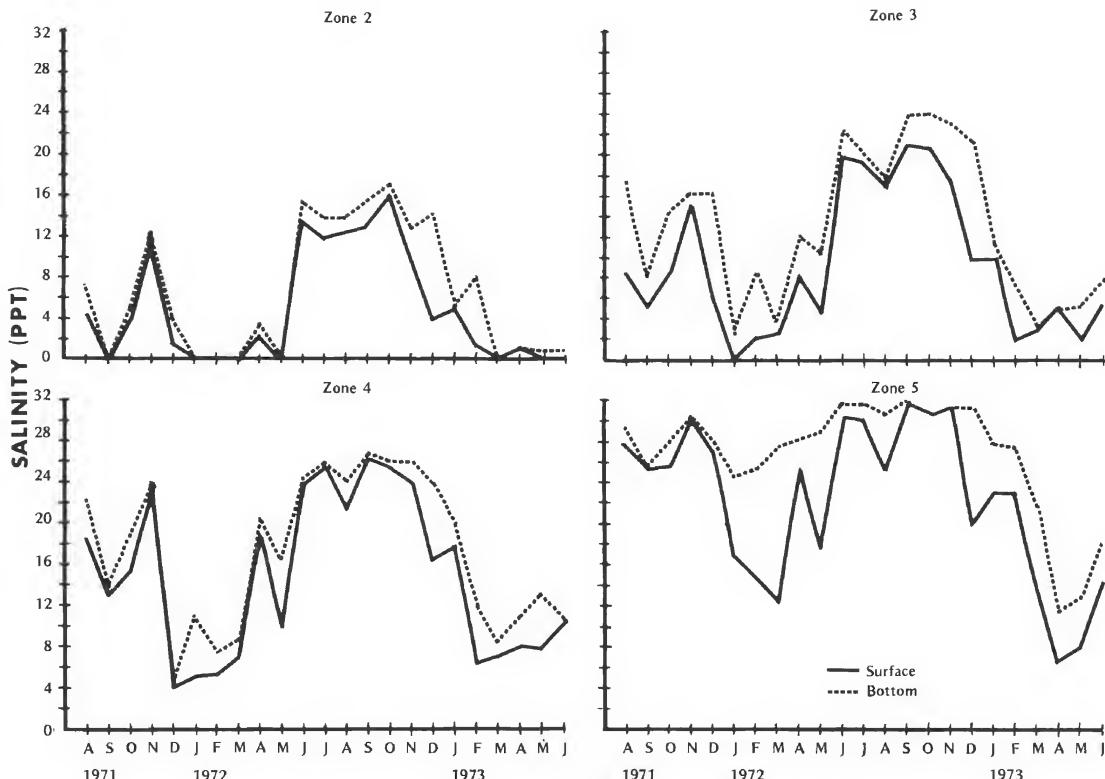


Figure 4. Average monthly surface and bottom salinities, zones 2 through 5.

salinities ranged from a low of 2.3 ppt in January 1972 to a high of 24.0 ppt in October 1972. Vertical gradients ranged from 0.0 ppt (April 1973) to 11.3 ppt (December 1972).

Zone 4 salinities fluctuated from a low of 4.0 ppt in December 1971 to a high of 26.3 ppt in September 1972. Bottom salinities ranged from 4.7 ppt in December 1971 to 26.7 ppt in September 1972. Vertical gradients ranged from 0.4 ppt (September 1972, June 1973) to 7.7 ppt (December 1972).

The lowest average surface (6.7 ppt) and bottom (11.3 ppt) salinities in zone 5 were observed in April 1973. Highest average surface and bottom salinities were recorded in September 1972, 31.7 ppt and 32.0 ppt, respectively. Vertical gradients ranged from 0.0 ppt (October–November 1972) to 15.0 ppt (March 1972).

Seasonal and areal distributions of salinity were similar to the patterns of isohalines reported for Mississippi Sound by Christmas and Eleuterius (1973).

Dissolved Oxygen

Dissolved oxygen on the surface always averaged higher or equaled bottom readings. Lowest readings were taken during late summer, followed by a steady increase in

dissolved oxygen concentrations through the winter. Bottom readings averaged from a low of 3.5 ppm recorded in zone 2 in September 1972 to a high of 9.6 ppm recorded in January 1973 in zone 3. Surface averages were not observed to fall below 5.0 ppm, ranging from 5.6 ppm in zone 3 in August 1971 to 10.4 ppm in zone 3 in May 1973.

Occasionally, low individual readings were observed in all zones. Low values were usually associated with oxygen depletion in the bottom water of deep holes, or in association with swarms of the ctenophore *Mnemiopsis mecradyi*. These organisms were often collected in large numbers at both trawl and plankton stations during summer months. Christmas and Eleuterius (1973) noted that occasional temporary oxygen depletion in bottom waters is a natural phenomenon in Mississippi Sound in areas not associated with excessive BOD (biological oxygen demand) from domestic and industrial effluents.

Catch Per Unit of Effort

A total of 670 (trawl, seine, marsh net) samples collected 5,340 blue crabs from July 1971 through June 1973. An overall catch per unit of effort (all zones and all gear types combined) of 8.0 was noted for the 2-year period.

The 16-foot trawl and the 50-foot bag seine were most effective in the collection of juveniles and sub-adults.

Seine

The overall mean catch per seine haul was 8.4 during the first 12 months and 4.1 in the second period, giving an average 6.7 crabs per haul for the 24 months. Monthly means (all zones combined) ranged from a low of 0.8 in April 1973 to a high of 20.3 in June 1972. Means were 10.0 or above in July and December of 1971 and in January, June and August of 1972. High catches were associated with the appearance of large numbers of small crabs (below 40.0 mm carapace width) in shallow waters.

Seine hauls in zone 2 averaged 3.6 for the 2-year period. Yearly means were 2.9 (1971-1972) and 5.1 (1972-1973). Monthly means were below 5.0 crabs per haul for 20 of the 24 months. Highest average catches occurred in December 1971 (12.5), August 1972 (28.0) and October 1972 (20.0).

The yearly mean catch per seine haul in zone 3 was 11.4 during the first year, dropping to 4.6 during the second year. The overall mean catch for the 2-year period was 8.5. Monthly means ranged from 0.0 in January 1973 to 48.5 in June 1972, and were below 5.0 crabs per haul in 11 of the 24 months. Mean catch per haul was greatest in December 1971 (27.0) and June 1972 (48.5).

Crabs were absent from seine hauls in zone 4 in February and April of 1973. The highest average catch (38.5) was recorded in January 1972. Hauls averaged less than 5.0 crabs in 12 of the 24 months. The overall mean catch per haul for the 2-year period was 8.2, with yearly means of 11.7 (1971-1972) and 4.0 (1972-1973).

Seine hauls in zone 5 averaged less than 5.0 crabs in 18 of the 24 months. Yearly means of 5.4 and 2.2 were recorded for the first and second study years, respectively, with an overall 2-year mean of 4.2. Monthly means ranged from 0.0 (July 1971; June, July and September 1972; March, April and May 1973) to 19.5 (January 1972).

Trawl

The yearly mean catch per 10-minute trawl haul varied from 7.2 (1971-1972) to 16.5 (1972-1973), with an overall mean catch of 11.9 for the 2-year period.

Monthly means, all zones combined, ranged from a low of 0.9 in August 1971 to a high of 50.7 in March 1973. Monthly means were above 10 crabs per trawl in 11 of the 24 months. Maximum trawl catches during both study years occurred from late winter to spring or early summer. The monthly mean catch per haul was greatest from January through April in 1972 and from January through June of 1973.

Crabs were periodically abundant in trawls in zone 2 with the monthly mean catch per haul ranging from 1.0 (August 1971, June 1972) to 46.7 (March 1973). Yearly means were 8.8 (1971-1972) and 13.6 (1972-1973), with an overall catch per haul of 11.1 for the 2-year period.

Zone 3 produced the highest overall mean catch for the 24-month period (24.8 crabs/haul), the highest yearly means

of 13.0 (1971-1972) and 30.0 (1972-1973) and the highest monthly mean of 103.0 crabs per haul in March 1973. Juvenile crabs were particularly abundant in this zone from January through June of 1973. Large aggregations of juveniles and sub-adults were collected in dredged navigational channels. A single 10-minute trawl haul in March 1973 yielded 224 individuals. Lowest monthly means occurred in August 1971 (1.3) and October 1972 (1.7). Trawl hauls were most productive in this zone in January 1972 (48.7/haul), March 1972 (36.7/haul), January 1973 (35.0/haul), February 1973 (43.7/haul), March 1973 (103.0/haul), April 1973 (44.3/haul) and June 1973 (45.7/haul).

Crabs were more abundant in trawl hauls in zone 4 in 1972-1973 than in 1971-1972, with yearly means of 22.2 and 5.5, respectively. Again in this zone, as in zone 3, there was a preponderance of small juveniles and sub-adults in maintained navigational channels. Lowest monthly means were recorded in August 1971 (1.0), September 1971 (1.3), July 1972 (1.2), September 1972 (0.3) and November 1972 (1.3). Crabs were most abundant during December 1971 (14.0/haul) and from December 1972 through June 1973 with monthly means of 19.7, 23.7, 47.0, 53.0, 58.0, 48.0 and 26.7, respectively. The average catch per haul in this zone for the 2-year study period was 13.8.

Sixteen-foot trawls pulled in zone 5 were rarely productive. Yearly means of 1.1 and 0.8 were recorded during 1971-1972 and 1972-1973, respectively. The average catch per haul was below 1.0 for 16 of the 24 months. The highest average catch of 6.3 occurred in July 1971. Means were 3.0 crabs or less for the entire study period, with the exception of July 1971. Juvenile crabs in this zone appeared to congregate in protected lagoons along the barrier islands. Seine hauls were generally more productive than trawl hauls in this zone. Although trawls pulled through the grass beds north of the barrier islands were usually void of crabs, Eleuterius (personal communication) found small blue crabs to be periodically abundant in dredge hauls in these areas.

To summarize, seine hauls indicated a continuing population of juvenile crabs in shallow water with maximum availability during the winter and summer. The overall mean catch per seine haul was highest in zones 3 (8.5) and 4 (8.2). Crabs were almost three times more abundant at seine stations in zones 3 and 4 during the first year of the study than the second year.

Crabs were periodically abundant in trawl hauls in all seasons. Highest numbers occurred from January through April 1972 and from January through June 1973. Zone 3 exhibited the highest yearly means (13.0 and 24.8) and zone 5 the lowest means (1.1 and 0.9) for both years of the study period.

The determination of a relationship between the magnitude of seine and trawl catches to the subsequent commercial catch was not attempted on the basis of two years of data.

Distribution by Temperature and Salinity

Forty-eight percent of all samples and 66% of all crabs were collected in salinities below 15.0 ppt. Highest average

catches were associated with salinities between 5.0 and 15.0 ppt and temperatures between 20.0 and 25.0°C.

Separating crabs by sex (crabs under 19.9 mm were not sexed) and carapace widths in intervals of 20.0 mm revealed similar ratios of males to females in each increment (20.0 to 200.0 mm). More (1969) noted that sex ratios of juvenile crabs in Texas bays were relatively constant at each salinity level. The established differential distribution of adult male and female crabs was not evident. Two factors probably account for the lack of salinity preference observed. Since 83% of all crabs collected were below 100 mm carapace width, it is obvious that the 16-foot trawl was not efficient in the capture of adult crabs in Mississippi Sound. The salinity-temperature optima, as well as the equal male to female ratios, suggest that maximum availability of adults to trawl hauls occurred during the warmer months when mixed populations, coincident with mating, were abundant in the middle estuary.

Distribution by Habitat

Juvenile blue crabs were collected over a wide range of temperature and salinity, but were most abundant in the brackish waters of zones 3 and 4. Zone 3 had the greater catch per unit of effort. Both zones 3 and 4 contain extensive marsh areas which offer both food and protection for crabs. Crabs in these zones congregated in dredged navigational channels as well as along the marshes that fringe the bays and coastline. Channel depths in zones 3 and 4 vary from a few feet to over 30 feet and are characterized by soft mud bottoms. It is probable that these channels act as reservoirs for the collection of food and offer protection. Substrate appears to be an important factor in the distribution of juvenile crabs and their abundance over soft mud bottoms has been well documented (Tagatz 1968a, More 1969, Holland, Aldrich and Strawn 1971, Adkins 1972b). More (1969) indicated that the distribution of juvenile crabs in Texas bays may be related to bottom type as well as to salinity. Maximum numbers of young blue crabs in Mississippi Sound were associated with mud bottoms. Small crabs were consistently taken in all zones where a marsh habitat was encountered, although variations in abundance were evident. Seines pulled from open sand beaches extending to mud bottoms were also productive. Few crabs were seined off open sand beaches where adjacent sand bottoms were. Dredged channels were more productive than open water areas.

Preliminary analysis of data concerning the distribution of *C. similis* suggests that perhaps periodic overcrowding may occur in zones 4 and 5 because of overlapping habitats. *Callinectes similis* juveniles and adults were seasonally abundant in these zones.

The distribution of adult females was limited by low salinity. Field observations and regular checks of the commercial catch established their predominance in zones 4 and 5. They were collected in fewer numbers in zone 3 and were rarely captured in zone 2. Adult males were most numerous in low-salinity areas, but were occasionally observed near the barrier islands. Males and females were

present in the middle estuary (zones 3 and 4) during mating seasons. The differential distribution of male and female crabs in relation to salinity has been documented by Churchill (1919), Gunter (1950), Daugherty (1952), Van Engel (1958), Darnell (1959), Tagatz (1968a), More (1969) and Adkins (1972b).

Adult males were collected throughout the year in low-salinity areas, but adult females were conspicuously absent from trawl hauls during winter months. Whether this absence was because of the relative ineffectiveness of the 16-foot trawl in the capture of adults, the migration of females to Gulf waters with decreasing water temperatures, or the effect of the intense fishing effort during the summer has not been determined.

Spawning, Maturation and Mortality of Female Crabs

Mature females collected in routine sampling as well as females obtained from the commercial catch were examined to determine ovarian development. The ovarian stages described by Hard (1942) were used to define the reproductive potential of the population.

Recently mated females (Stage I) and crabs with developing ovaries (Stage II) were observed in the spring, summer and fall. Females with mature ovaries (Stage III) occurred throughout the year. The appearance of berried females (Stage IV) in March and April indicated that overwintering Stage III females spawn when water temperatures begin to rise in the spring. Stage IV crabs were most abundant during the middle and late summer, corresponding with the influx of "Gulf" crabs from offshore waters. Stage V crabs appeared during the summer providing evidence that some females spawn twice in the study area.

Mating crabs were noted in zones 3, 4 and 5. Spawning took place in zones 4 and 5, with hatching of the eggs taking place in zone 5 (crabs with late sponges usually moved to higher salinity waters to hatch their eggs).

During August 1972, hundreds of spent female crabs littered the Gulf beach of Cat Island. These crabs were heavily infected with *Carcinonemertes carcinophila*, *Octolasmis lowei* and *Urosporidium crescents*. Most were heavily fouled with barnacles. Mortalities of this type have been observed in previous years along one or more of the barrier island beaches by Christmas and McIlwain (personal communication).

Growth

Early crab stages (2.5 to 9.9 mm carapace width) were collected in 19 of the 24 months under study, indicating growth to the juvenile population throughout the year (Figure 5).

Using combined seine and trawl data, growth was estimated by tracing modal progressions in monthly width-frequency distributions. Distributions were plotted by individual zone as well as by combined zones. The dominance of early crab stages made precise interpretation of width-frequency data difficult. The difficulty of obtaining reliable information concerning the growth of crustaceans using

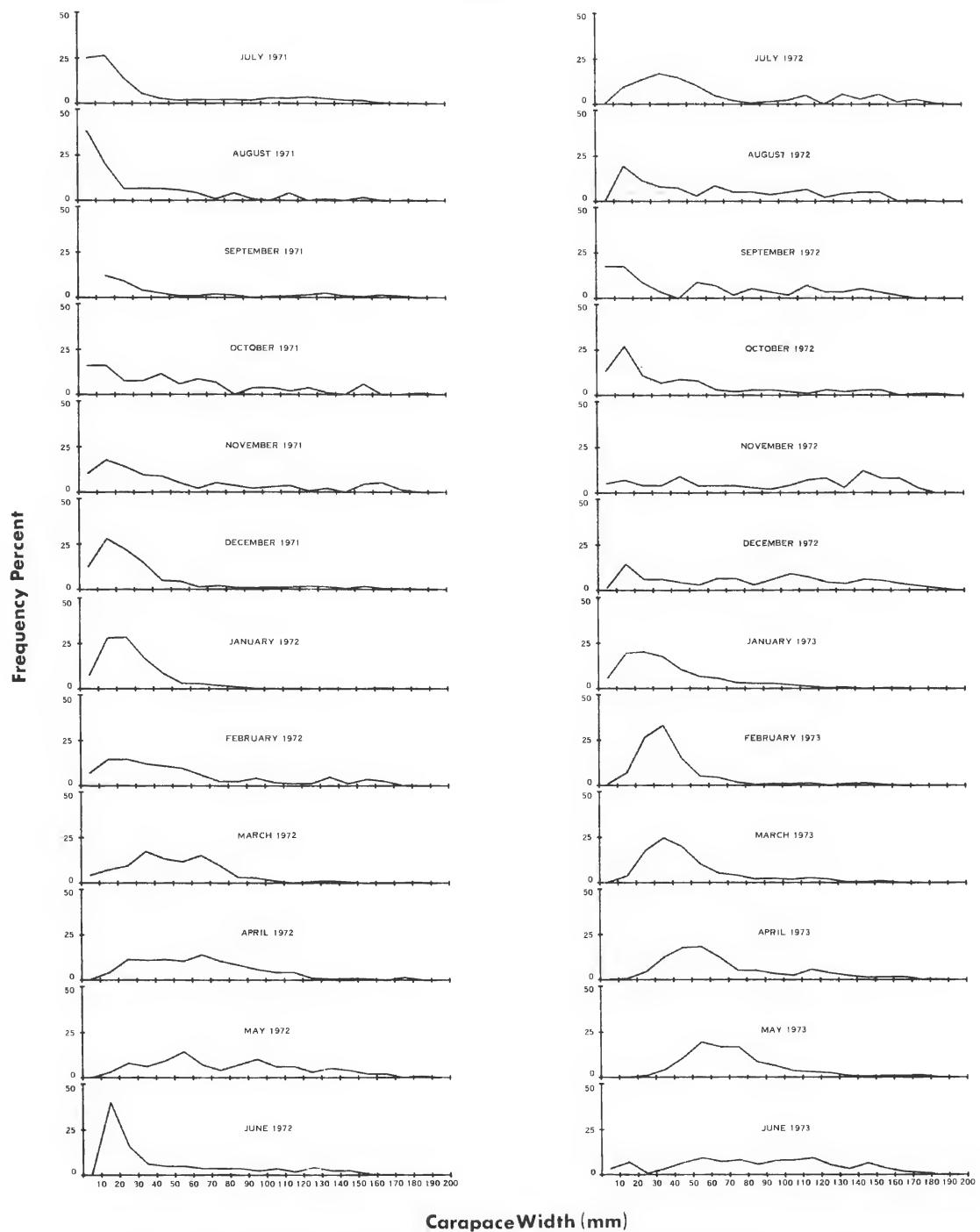


Figure 5. Width-frequency distributions of blue crabs taken from Mississippi Sound, July 1971–June 1973.

frequency distributions has been discussed by Darnell (1959).

Width-frequency distributions showed minor modes despite the continuous movement from early crab to juvenile stages. A mode established in July 1971 in zone 4 and followed through January 1972 indicated rapid growth of juveniles to adults (Figure 6). Crabs which were 15.0 mm carapace width in July were 165.0 mm carapace width in January, a gain of 150.0 mm in 6 months or an average gain of 25.0 mm per month. A second mode was observed from January 1972 through June 1973 when data from all zones were combined. Crabs which were 30.0 mm carapace width in January were 150.0 mm carapace width in June, a gain of 120.0 mm in 5 months, or an average gain of 24.0 mm per month. Growth rates (24.0–25.0 mm/month) determined for Mississippi Sound averaged higher than rates determined by More (1969) for crabs in Texas bays (15.3–18.5 mm/month) and Darnell (1959) for crabs in Lake Pontchartrain (16.7 mm/month).

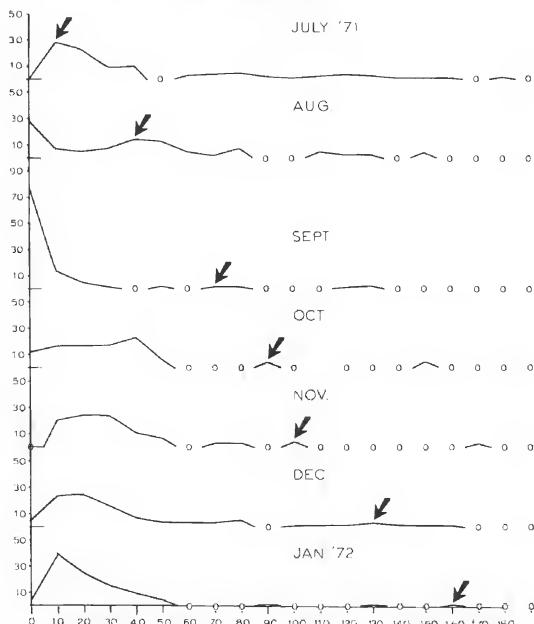


Figure 6. Width-frequency distributions of the blue crabs taken in zone 4, July 1971–January 1972.

Winter temperatures in Mississippi Sound did not appear to greatly alter the molt interval during the 2 years under study. In January 1972, 13.5% of the population sampled were in the process of shedding or had recently shed.

Data indicated that it is possible for a crab to attain commercial size in Mississippi within 10 months following hatching.

Tagging

The tagging program was divided into two phases. Phase I

of the program was designed to determine the origin of the crab population moving into Mississippi Sound in the vicinity of Cat Island with the advent of cold weather. Phase II included the tagging of crabs in the St. Louis Bay, Biloxi Bay and Pascagoula River estuaries in order to determine if movement exists between estuarine systems.

Phase I—Release

According to local crab fishermen two major influxes of mature female crabs occur in Mississippi Sound. The first migration takes place in October or November and the second in the months of July and August. Repeated interviews with crab fishermen and field observations during the early part of the study established that no winter fishery for crabs existed in the areas near Petit Bois, Horn or Ship Islands. There was very limited crabbing in the Sound in the immediate vicinity of Biloxi Bay. Winter crabbing in the Sound was centered almost exclusively in the area near Cat Island where there was a sizable population of overwintering, gravid female crabs.

Adult blue crabs (155 males; 868 females) were released in three locations in Lake Borgne and in one location in Mississippi Sound (Figure 7, Table 1). All crabs tagged were obtained from a commercial source and were released near the area of capture.

TABLE 1.
Summary of release data for crabs tagged during Phase I.

Release Location	Date	Males Released	Females Released	Total
1 mile S. mouth of Pearl R.	11-22-71	19	4	23
1 mile E. of Grand Island	11-23-71	8	62	70
4 miles W. Grand Island	11-24-71	27	370	397
2 miles E. St. Joseph Point	12-8-71	101	432	533
TOTAL				1,023

Phase I—Recovery

Total recoveries through June 1975 numbered 304 (29.7% recovered), of which 44.5% were males and 27.1% were females. Ninety-eight percent of the recovered crabs were captured by commercial crab fishermen using standard wire crab pots. One percent of the crabs were recovered with other commercial gear (shrimp trawls; oyster dredges). Sport fishermen contributed to 1% of the returns. Tagatz (1968a) reported that 97% of the recoveries in St. Johns River, Florida were by commercial gear, with sport fishermen contributing only 3% of the returns. Cargo (1958) also found returns high from commercial fishermen. In direct contrast, More (1969) noted that recreational crabbers were responsible for 80% of the recoveries in Galveston Bay.

Ninety-three percent of the crabs returned during the early months of this study were recovered from seven areas (Figure 7). For this discussion these areas have been given Roman numerals I–VII. A brief description of these areas follows.

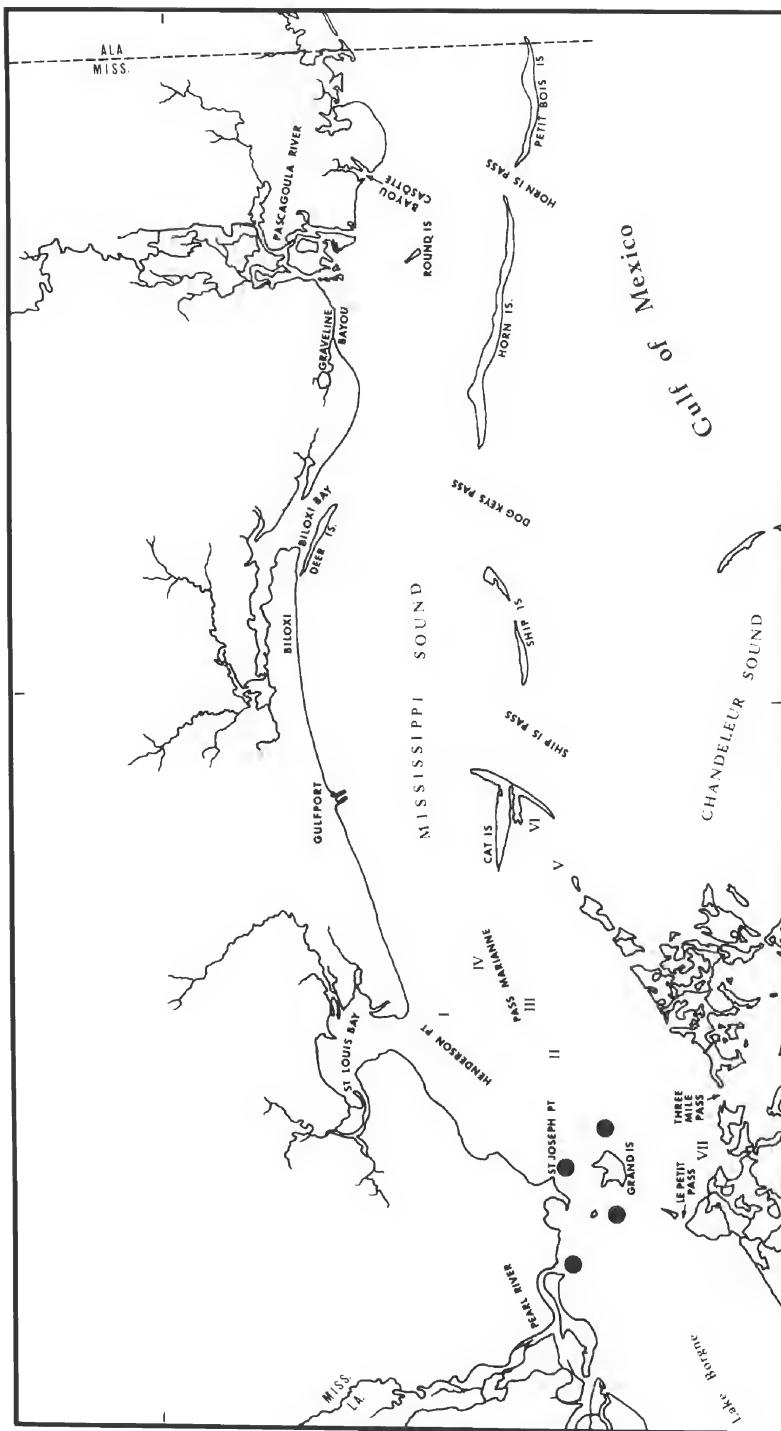


Figure 7. Location of release points and recapture areas for crabs tagged during Phase I.

Area I is located due south of Square Handkerchief Shoal in an area of active oyster production. Water depth in the area varies from 7 to 16 feet. This region was fished from November through the week of December 13, 1971 with approximately 200 commercial crab pots.

Area II is located north of Grand Island Channel in approximately 12 feet of water. This is also an area of active oyster production. Areas I and II were worked by menhaden fishermen who crabbied seasonally during the winter. Crab pots in this area numbered approximately 250.

Area III includes Telegraph Oyster Reef (Merrill Coquille) and surrounding waters. Water depth varies from 2 feet over the reef to 14 feet. Approximately 200 pots were located in the Telegraph Reef vicinity from September through December 16, 1971.

Area IV encompasses Pass Marianne Oyster Reef and the tail of Square Handkerchief Reef. Water depth varies from 4 feet over the reefs to 14 feet in Pass Marianne. This area was worked by crab fishermen from Bayou La Batre, Alabama as well as local crabbers. The number of pots in this area varied.

Area V extends along the east and west banks of Cat Island Channel and is located along an old oyster reef. Pots were moved into this area from Areas I and II the last week in December 1971. Approximately 450 pots were fished in this area through February 14, 1972.

Area VI is located south of the Middle Spit of Cat Island in the Smuggler's Cove region. Oysters are scattered in this area. Two hundred pots were moved into this area from Area III after December 16, 1971.

Area VII extends along the salt marsh from Le Petit Pass to Three Mile Pass, Louisiana. This is an area of scattered oyster production. Depths are shallow, ranging from 3 to 8 feet. Four hundred pots were fished by a single crabber in this region.

Tables 2 through 5 contain recapture data for crabs released during Phase I. The number of males (M) and females (F) recovered, distance traveled in nautical miles, time (days) from release to recapture and the direction of travel in degrees (approximate) are given.

Of the 69 males and 235 females returned, 92.3% of the females and 81.2% of the males were recovered northeast of the release sites. These crabs traveled 2 to 38 nautical miles. Time between release and recapture varied from 4 to 261 days.

TABLE 2.
Recapture data for crabs released 1 mile south of the mouth of Pearl River, November 22, 1971.

Recapture Area	M	F	Miles	Time	Degrees
III	1	13	35	74	
IV	2	15	31-54	71	
V	1	19	36	85	
VII	4	8	36	136	
Lake Pontchartrain	1	17	165	270	
St. Joe Channel	1	4	197	80	
TOTAL	10				

TABLE 3.
Recapture data for crabs released 1 mile east of Grand Island, November 23, 1971.

Recapture Area	M	F	Miles	Time	Degrees
I	1	2	6	19-23	35
II		2	3	11-21	46
III		2	8	25-38	53
IV		6	10	21-60	54
V		8	14	37-80	81
VI		2	16	65-93	74
VII		2	5	21-35	180
Deer Island		3	31	99-145	65
TOTAL	1	27			

TABLE 4.
Recapture data for crabs released 4 miles west of Grand Island, November 24, 1971

Recapture Area	M	F	Miles	Time	Degrees
I	1	7	11	10-28	57
II		4	9	13-23	64
III	2	5	13	16-27	67
IV		20	15	18-49	63
V	2	24	20	30-103	80
VI		14	22	36-103	75
VII	4	11	7	15-34	127
Biloxi Bridge	1	38	143		65
Deer Island	2	36	144-183		68
Pass Christian	3	17	176-181		53
Biloxi Lighthouse	1	35	201		64
Gulfport Harbor	1	26	213		57
Lake Borgne	1		49		
TOTAL	9	94			

TABLE 5.
Recapture data for crabs released 2 miles east of St. Joseph Point, December 8, 1971.

Recapture Area	M	F	Miles	Time	Degrees
I	12	18	4	4-14	53
II	5	12	2	4-15	83
III	5	11	7	8-27	77
IV	4	11	9	9-38	69
V	10	26	14	20-91	90
VI	5	26	15	29-104	84
VII	4	5	8	20	180
Bay St. Louis Bridge	2	8		261	32
Mississippi City	1	21		103	63
Pass Christian	2	1	10	167-237	52
Biloxi Lighthouse	1	28		187	66
Biloxi Back Bay	1	31		194	66
Deer Island	1	30		127	72
TOTAL	49	114			

Ten percent were recovered at points southeast to south of the release areas. These crabs were recovered in Area VII in lower Lake Borgne. Travel distance ranged from 5 to 8 miles in 15 to 16 days.

A single male crab was returned west of the point of

release. This crab was tagged 1 mile south of the mouth of Pearl River and was recovered 5 1/2 months later from Lake Pontchartrain.

Discussion

From November 1971 through March 1972, commercial crabbing was concentrated in one or more of the areas in western Mississippi Sound and lower Lake Borgne (Figure 7). Nearshore crabbing was conducted on a limited basis in the Biloxi Bay area near Deer Island. Sport crabbers did not fish during this period. Early tag returns necessarily reflect the fishing pressure in these locales. Considering the bias exerted by the concentrated effort in Areas I-VII and the limited effort along the coastline, it is possible that nearshore returns would have been greater if crabbing had been homogeneously distributed throughout the Sound. Fishing effort along the coastline did not increase until the close of the oyster season in May.

The Deer Island recoveries were the first indication of movement into coastline areas with increasing water temperatures. One berried female was recovered at Deer Island 145 days after release. It is probable that the early spring spawners in Mississippi Sound are part of this population of crabs. Berried females returned from coastline areas had yellow sponges. Such crabs usually move into higher salinity waters prior to hatching of the eggs. No berried females were returned from waters south of the Intracoastal Waterway; this, again, is a function of the fishing effort along the coastline during the spring and summer.

The rate of recovery (29.7%) in the present study compares favorably with the recovery rates of Cargo (25.0%) in 1958 and Tagatz (35.0%) in 1968. The low percentage return (6.1%) reported by More (1969) was attributed to movement of the crabs away from the fishing grounds.

These results appear to confirm Darnell's theory that mated females leave the low-salinity waters (usually below 10.0 ppt) of Lakes Pontchartrain and Borgne to overwinter in Mississippi and Chandeleur sounds. A definite salinity gradient exists along a transect from the mouth of Lake Borgne eastward to Pass Marianne and Cat Island, where the average yearly salinities are 22.8 and 23.5 ppt, respectively. Ballard and Abbott (1969), working with crabs from Mississippi Sound, and Tagatz (1971) found that osmotic stress was placed upon the mature female crab in waters of low salinity and low temperature. Therefore, it would seem that migration in this particular instance might have been related to temperature and salinity. Ballard and Abbott (1969) also noted that high temperatures may favor tolerance of lower salinities by lowering the blood concentration and thus reducing osmotic work. This may, in part, explain the movement of these females into lower salinity shoreline waters as spring temperatures increase.

It is interesting that Cargo (1958) found that females in Chincoteague Bay moved in a southerly direction even if released at points where high-salinity water was to the north. He believed that the lack of a single continuous salinity gradient in the Bay might affect migratory patterns, and that the established gradient in Chesapeake and Delaware

bays might serve as an orienting factor. The movement of the Chincoteague Bay females to the south, regardless of the proximity of a salinity gradient, suggests that other factors may be influential in establishing migratory patterns in that area.

Physiographically, Mississippi's estuarine area is compound, consisting of a system of estuaries adjoining a lagoon (Emery and Stevenson 1957). The Sound is an elongate body of water partially separated from the Gulf of Mexico by a series of barrier islands. The complexity of this system does not readily lend itself to concise hydrological classification. Both north-south and east-west salinity gradients exist in addition to vertical salinity gradients. It is evident from the migratory pattern established in Phase I that travel along a salinity gradient does exist, but the forces that influence travel over a particular gradient are not known.

The migration of males parallel to females in time and distance, as observed by Tagatz (1968a), occurred in the present study as well. Tagatz noted that this migration did not occur in previous studies of crab movements.

The high rate of returns in the present study suggests that the commercial crabbers are effectively fishing this population of crabs.

Phase II—Release and Recovery

Phase II of the tagging program was carried out from May through July 1972. Crabs were released in the Biloxi Bay, St. Louis Bay and Pascagoula River estuaries.

Crabs were released in three locations in the Biloxi Bay estuary (Figure 8). Of 214 females and 78 males released, 86 females and 39 males (or 42.8%) were returned. With a single exception, all recoveries occurred within 35 days of release and 22.0% were recaptured within a week. The computation of distance traveled was not attempted. Direction of travel was random, with movements in and out of Biloxi Bay and east and west along the coastline. Males and females appeared to restrict movements within the limits of the Biloxi estuary and no migratory pattern was evident. In June 1974, 2 years after tagging, a male crab from the Biloxi release was recaptured in Pascagoula River, 8 miles upstream from the mouth. Adding these years to the time required to attain adult size, it is evident that some crabs survive for a period of 3 years in Mississippi waters.

In St. Louis Bay (Figure 8), 140 males and 112 females were released in two locations. Forty males and 13 females were returned for a recovery rate of 21.0%. All recoveries were made within 34 days of release. Movement in St. Louis Bay, as in Biloxi Bay, appeared to be random and a directed migratory pattern was not observed. Crabs moved randomly between the Bay and Sound and along the coastline. All recoveries were within the St. Louis Bay estuary.

Returns from the Pascagoula River estuary were low with only 4.8% of the crabs recovered. Crabs were released in a single location (Figure 8) and all recoveries were within 46 days of the release date. Movement between estuaries was observed when two male crabs were recovered near the St. Louis Bay Bridge and a single male was captured along the Biloxi beach front. Low returns may in part be explained by

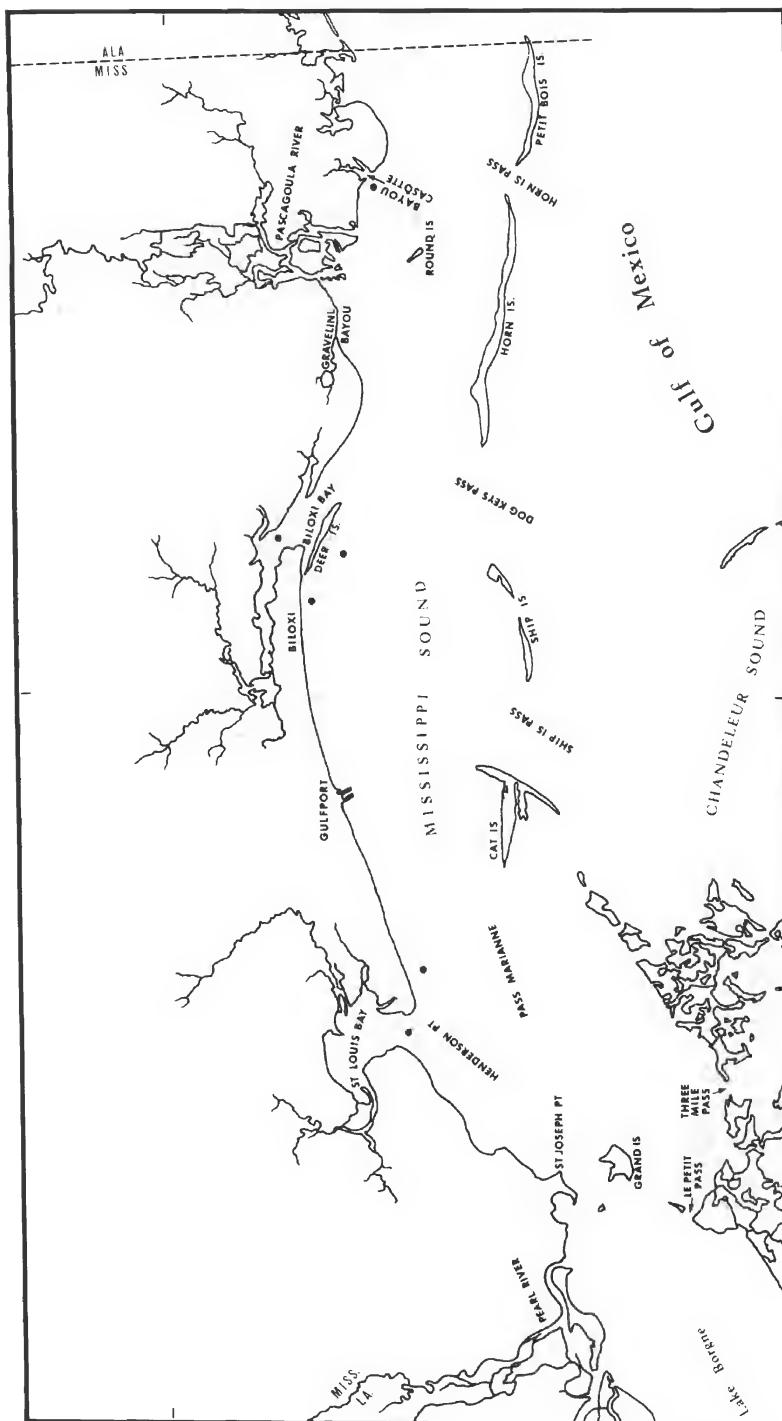


Figure 8. Location of release points for crabs tagged during phase II.

the low fishing effort in the Pascagoula system and the possibility that easterly movement made these crabs unavailable to local crab fishermen. Periodic checks of crab processors in Bayou La Batre, Alabama did not yield additional returns.

Returns from all of the estuaries necessarily reflect local fishing pressure and patterns of fishing. Fishing effort along the coastline during the spring and summer is extremely heavy from Graveline Bayou on the east to Grand Island on the west.

Parasites and Epizoans

Metacercariae of the trematode *Carneophallus basodactylophallus* were found to be infested with a haplosporidian hyperparasite tentatively identified as *Urosporidium crescens* (Overstreet 1971, personal communication). Metacercariae containing the hyperparasite were found in the hepatopancreas and musculature of the crab as well as in the gills. According to Perkins (1971), rupture of the metacercariae is necessary for the release of the spores of *U. crescens*, and this occurs after the death of the crab. He found no evidence that the trematode caused mortalities in crabs.

With the maturation of the spores of *U. crescens*, the metacercariae became blackish in color. Metacercariae containing such spores cause the condition known as "buckshot" by local crab fishermen. Crabs thus affected are also known as "pepper" crabs.

Crabs infected with *U. crescens* were taken in all seasons. Infections were present in mature and immature crabs of both sexes. Since the presence of *U. crescens* was detected only by gross observation of the mature spores, it is highly probable that light or very early infections were not noticed. No data were taken on the incidence of infection by the metacercariae alone. Detailed information concerning the life history of *C. basodactylophallus* has been published by Bridgman (1969).

The rhizocephalan parasite, *Loxothylacus texanus* was found on less than 1.0% of the crabs. Christmas (1969) noted that the rate of infection in 1966 in Mississippi Sound was negligible. Gunter (1950) observed that only 1.5% of the crabs collected in Aransas and Copano bays, Texas were parasitized. More (1969) found 8.0% and 5.8% infection rates in crabs examined from the lower Laguna Madre and upper Laguna Madre, respectively, with the incidence of infection never exceeding 1.0% in other Texas bays. The parasite appears to be a more serious problem in Louisiana waters. Ragan (personal communication) reported that infection rates in selected Louisiana estuaries may approach 50% during the warmer months. Notes on the occurrence and distribution of this parasite in Louisiana waters (Terrebonne Parish) have been published by Adkins (1972a). Reinhard (1950a, 1950b, 1951) discussed the morphology and life history of this parasite and its effect on the morphology of the blue crab.

Carcinonemertes carcinophila, a parasitic nemertean, was observed on the gills and egg masses of mature female crabs. Hopkins (1947) discussed the use of this worm as an indicator of the spawning history of *C. sapidus*.

Levinseniella (Monarrhenos) capitanea a microphallid trematode, was described from metacercariae found on the hepatopancreas and gonads of the blue crab. Crabs infected with these metacercariae were collected in the area of Racoon Island, Louisiana in July and August of 1971 and from Cat Island, Mississippi in August 1971 and 1972 (Overstreet and Perry 1972).

Epizoic barnacles (*Octolasmis lowei*) were noted on the gills of male and female crabs collected from zones 4 and 5. Most infections were observed on mature individuals. More (1969) noted that 57.0% of the mature female crabs examined from the Gulf surf off Texas in 1967 were infected with this barnacle.

Leeches (*Myzobdella lugubris*) were found on specimens from areas of relatively low salinity. In all cases the leeches were attached to the abdomen and no penetration of the carapace was observed. Hutton and Sogandares-Bernal (1959) noted that this leech may have been responsible for mortality of the blue crab in Bulow Creek, Volusia County, Florida.

Chitinoclastic bacteria were found associated with lesions on the carapace of many crabs. These necrotic areas were visible as brown depressions on the carapace. Rosen (1967) stated that at present "we can only speculate about the causative agent of these lesions—the presence of chitinoclastic bacteria in the necrotic tissue does not *per se* implicate them as a primary causative agent of the necrosis." Cook and Lofton (1973) isolated chitinoclastic bacteria associated with shell disease in the blue crab and penaeid shrimp. Although one of the isolates (*Beneckeia* type I) was present in all cases of shell disease encountered, there was no evidence of penetration of the epicuticle by the bacteria.

Branchiobdellid annelids were noted in the gill chambers of crabs taken from low-salinity waters. Blackford (1966) in her study of the ecology and morphology of branchiobdellid annelids epizoic on *C. sapidus*, noted that the branchiobdellids infecting crabs in Louisiana were probably commensal, and not parasitic. She reported that these annelids are not salinity tolerant and must drop off of the host when it leaves low-salinity areas.

Barnacles were the most common epizoans found associated with the blue crab in the study area. Other epizoans included mussels and various species of ectoprocts.

COMMERCIAL FISHERY STUDIES

Blue crab landings in Mississippi averaged 1,712,000 pounds for the 20-year period 1953–1972 (Lyles 1969). Yearly landings varied from a low of 907,000 pounds in 1962 to a high of 3,003,000 pounds in 1959. Landings were higher than the 1,712,000 pound average for 9 of the 20 years. Historical fishery statistics show peak landings for the state during 1945 (5,639,000 pounds) and 1948 (5,503,000 pounds). Landings do not necessarily reflect actual blue crab production in Mississippi since they include only those crabs that enter local processing plants. Mississippi landings do not include crabs taken in local waters and landed in neighboring states, nor do they include the catch of subsistence and sport fishermen.

Crab processing plants in Mississippi are mainly small operations. Only nine plants were in operation during the study period, and five also processed other seafoods (shrimp, oysters). In some instances, larger processors supplemented the local catch with crabs trucked from Louisiana or Alabama. The local winter catch supported a few of the plants but most either shut down crab operations or turned to "trucked" crabs landed in other states. Many of the plants operated below capacity due to the scarcity of pickers. Pickers were paid 35 to 60 cents per pound of picked meat throughout the study period.

Commercial crabbers were paid 10 to 14 cents per live-weight pound, depending upon the availability of crabs.

Most professional crabbers worked a five- to six-day week during the warmer months. Those who continued to crab during the winter averaged a three- to four-day week depending upon weather conditions. Many crabbers turned to oystering in the colder months.

Most of the catch was taken by means of a crab pot, with "trawl" crabs occasionally entering the catch.

The gulf crab, *Callinectes similis* did not enter the commercial catch. The stone crab, *Menippe mercenaria* was occasionally observed in the catch but was not processed.

Distribution and Composition of the Commercial Catch

The sex ratio of crabs landed in Mississippi was found to be dependent upon the season and the area fished. During winter, crabbing was concentrated in the vicinity of Cat Island and Pass Marianne. A few continued to crab in the Biloxi Bay area, their pots being located south of Deer Island. The winter catch for both areas was comprised almost entirely of mature female crabs. No crabbing was done along Horn and Ship islands during the winter. Weather conditions during the winter, the long distance to these islands, and the nature of the currents were the major factors involved.

During the spring, more areas within the Sound were crabbed. Spring and summer catches were mixed. Males were more abundant near sources of freshwater runoff, and females were generally more abundant in areas of intermediate and high salinities.

With the decline in abundance of crabs in the late summer and early fall, crabbers either turned to oystering or moved their pots to the winter crabbing areas.

The carapace width of crabs examined from the commercial catch ranged from 112.0 mm to 204.0 mm.

Catch Per Unit of Effort

Data used to determine the catch per unit of effort were obtained weekly from records maintained by cooperating processors and fishermen. These data included 19.7% of the total landings for the study period. Information furnished by them gave the numbers of pots fished, length of time the pots were fished, amount of the landings and location of

the pots. The number of pots used by fishermen varied from 65 to 400.

Catch per unit of effort (pounds/pot day) was calculated as follows:

$$\text{CPUE (pounds/pot day)} = \frac{\text{Total pounds caught on day X}}{\text{Number of pots used on day X}}$$

The results are illustrated in Figure 9. The catch of 7.2 pounds/pot day in June 1973 was the highest recorded in the monthly averages.

Rises in the catch per unit of effort closely followed the migration periods of mature female crabs into the Sound. Peaks were associated with the fall-winter arrival of females from Lake Borgne and the summer arrival of females from the Gulf. The spring rise appeared to be associated with the maturation of crabs, both male and female, with warming temperatures. Crabs that entered the catch during the spring were, in most instances, "new-shedders." Tagging studies indicated that some females which were ready to spawn or females with sponges that appeared in the spring catch belonged to the older group of crabs that overwintered in the Sound near Cat Island and Pass Marianne.

Landings used to determine the catch per unit of effort (Figure 9) included the catches of several seasonal crabbers working small numbers of pots. These fishermen did not "follow" the crabs but usually located their pots in areas easily accessible to the processor handling their catch. They consistently had a lower catch per unit of effort than the full-time professional crabbers.

Total fishing effort varied from 63,390 pot days in August 1972 to 9,000 pot days in February 1972. Since many factors affect total fishing effort (weather, seasonal nature of the fishery), variations in total effort did not always follow variations in catch per unit of effort. In addition, crab fishermen in Mississippi are limited by processors as to the number of pounds they may land during the summer when crabs are abundant. Although fishing effort during the summer could be increased, the present technological level of the industry necessarily limits the amount of crabs that can be processed. During the summer of 1973, crabbers were not put on a limit and crabs landed in excess of the processing capabilities of local plants were shipped out of the state (reflected in increased landings and catch per unit of effort for June 1973). More (1969) observed that values of catch per unit of effort indicated changes in crab abundance, but he was unable to correlate those values with changes in catch or effort.

Almost all of the crabbers interviewed expressed concern over the appearance of extremely small mature male and female crabs. These crabs, known as "button" crabs, appeared in larger numbers in the spring and early summer. Females with carapace widths of 112.0 mm were observed with sponges. The cause for the maturation of these small crabs has not been determined.

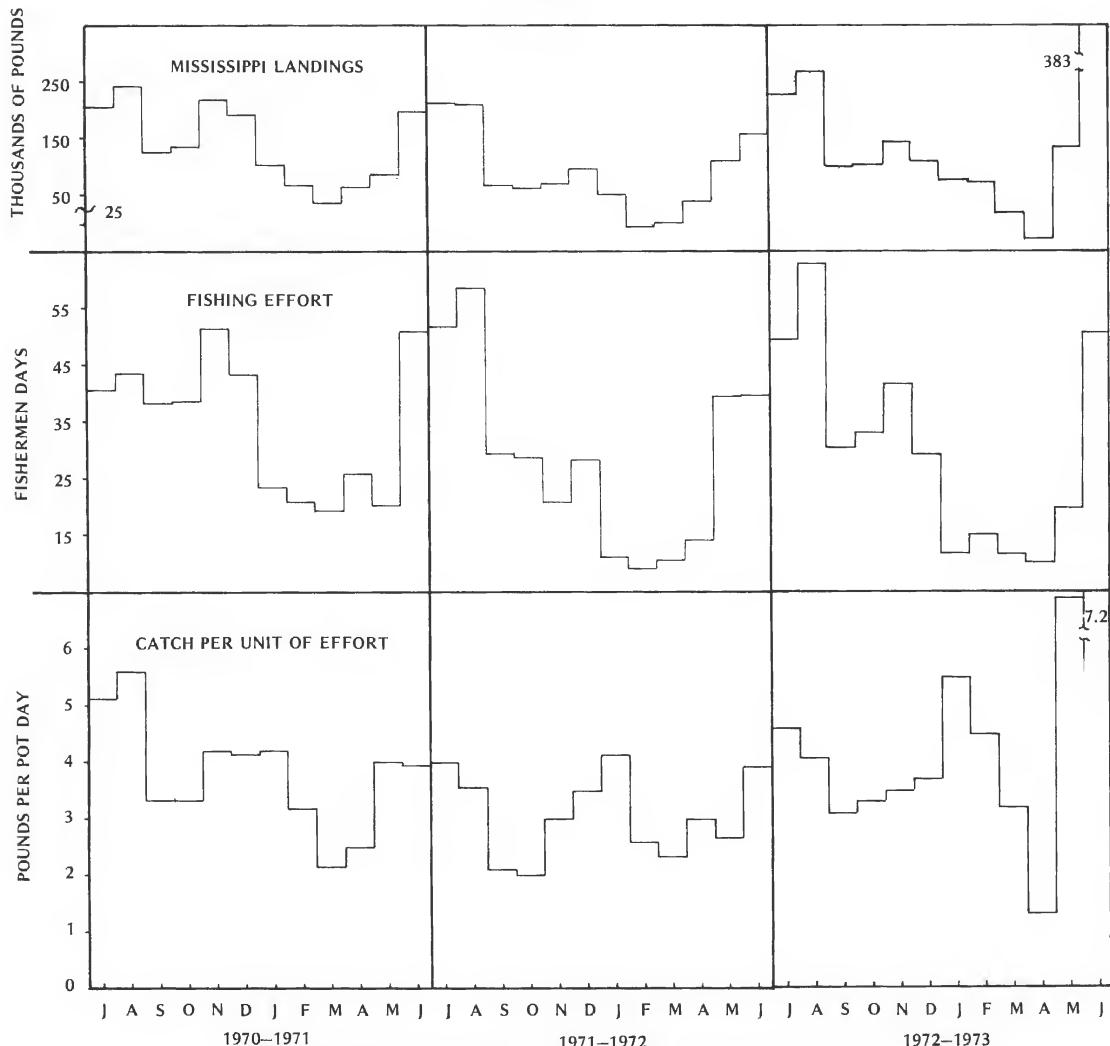


Figure 9. Monthly blue crab landings, fishing effort and CPUE in Mississippi Sound.

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Gulf Research Reports

Volume 5 | Issue 1

January 1975

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DOI: 10.18785/grr.0501.06

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Recommended Citation

De La Cruz, A. A., K. D. Chapatwala and W. E. Poe. 1975. Amino Acid Changes During In Vitro Decomposition of Marsh Plant Detritus. *Gulf Research Reports* 5 (1): 59-60.
Retrieved from <http://aquila.usm.edu/gcr/vol5/iss1/6>

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SHORT COMMUNICATIONS

AMINO ACID CHANGES DURING IN VITRO DECOMPOSITION OF MARSH PLANT DETRITUS¹

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ABSTRACT Dead plant material was collected from a tidal marsh, ground to a uniform size (250 μm) and decomposed in vitro at 30°C in darkness for 36 days. Crude protein, total amino acids, and essential amino acids increased from 19.0 to 31.0 mg/g, 11.1 to 17.6 mg/g and 5.8 to 8.1 mg/g respectively from day 0 to day 36. The amino acid and crude protein values observed in the detritus are generally low but the increment during decomposition is considered significant in terms of the marine consumers that depend on highly decomposed detritus for food.

INTRODUCTION

Tidal wetlands (e.g., salt marshes, mangrove swamps, eel grass and seaweed beds) have been reputed to be high producers of plant biomass (Keefe 1972; de la Cruz 1973) which is the major source of oceanic detritus. Studies by a number of investigators (Petersen 1918; Hickling 1961; Darnell 1964; de la Cruz 1965; Heald 1969; Odum 1970) have pointed to the value of plant detritus as food for estuarine and near-shore marine heterotrophs. A recent study by de la Cruz and Gabriel (1974) indicated a nutritive enrichment of marsh plant tissues during decomposition to particulate detritus. In a previous study (de la Cruz and Poe 1975), we have shown that amino acid concentrations increased during in situ decomposition of dead marsh plant materials to particulate detritus (2.5 mm). In this study, we considered the changes in amino acid levels during advanced stage of decomposition of detritus beyond the 2.5 mm particle size under laboratory conditions.

MATERIALS AND METHODS

Detritus was artificially prepared by collecting dead and partially decomposing plant material from a tidal marsh dominated by the giant cordgrass, *Spartina cynosuroides*, grinding it to a uniform size (250 μm) in a Wiley Mill. A 5-gram sample of the ground material was resuspended in each of five 1000-ml sterile flasks containing 600 ml of autoclaved estuarine water. Each flask was inoculated with 5 ml natural water from the marsh estuary and incubated in the dark at ambient summer temperature ($\approx 30^\circ\text{C}$). The flasks were aerated and the gentle bubbling caused slow agitation of the suspension.

At 0, 5, 13, 25, and 36 days, one flask was harvested, vacuum evaporated and dried at 103°C. One half gram sample was hydrolyzed in 6 N HCl for 24 hours according to the procedure of Smith et al. (1965). Amino acid analysis was performed according to the procedure we previously described (de la Cruz and Poe 1975) utilizing a Beckman Model 120C Amino Acid Analyzer.

Protein was estimated from total nitrogen ($\times 6.25$) determined by a modification of the Kjeldahl method (Assoc. Chem. 1965).

RESULTS AND DISCUSSION

The concentrations of the 17 amino acids analyzed, with the exception of histidine, increased during the vitro decomposition from day 0 to day 36 (Table 1). Aspartic acid, glutamic acid, proline, glycine, isoleucine, leucine and phenylalanine increased by as much as 62–100%. Since the plant material we used in the present study was collected from a *Spartina cynosuroides* marsh and presumably consisted mostly of dead *Spartina* plants, it is expected that the amino acid level of the artificially prepared detritus at day 0 is essentially the same as the amino acid values we previously obtained for dead *Spartina* tissue (de la Cruz and Poe 1975).

Total amino acid (AA) and crude protein (CP) increased by 27% and 13% respectively from day 0 to day 5; the levels remained virtually the same through the 25th day, and increased again by 25% and 45% respectively at day 36. The decline in AA/CP ratio in spite of increases in amino acid and crude protein indicates the occurrence of nitrogen sources (presumably ammonia and other nitrogenous metabolic products) in the suspension. Our previous study (de la Cruz and Poe 1975) on the in situ decomposition of marsh plant detritus also revealed a decline in AA/CP ratio despite increases in amino acids and protein. However, the increment in crude protein in the in situ studies is generally

¹Supported by the National Science Foundation Oceanography Section (NSF Grant No. GA-35715)

TABLE 1.
Amino Acid Analysis (mg/g) of Marsh Plant Detritus (250 μm)
After In Vitro Decomposition at 30°C in the Dark

Protein	Number of Days				
	0	5	13	25	36
Amino Acid					
Acidic					
Aspartic acid	1.2	1.7	1.7	1.8	2.1
Glutamic acid	1.1	1.7	1.8	1.8	2.1
Basic					
Lysine	0.7	0.7	0.7	0.6	0.8
Histidine	0.3	0.3	0.2	0.2	0.3
Arginine	0.6	0.7	0.8	0.8	0.8
Neutral					
Threonine	0.7	0.9	1.0	0.9	1.1
Serine	0.8	0.9	0.9	0.9	1.1
Proline	0.7	1.0	0.6	1.1	1.3
Glycine	0.8	1.0	1.0	1.1	1.3
Alanine	0.8	0.6	1.1	0.7	1.0
Valine	0.8	0.9	0.9	0.9	1.2
Isoleucine	0.5	0.7	0.8	0.8	1.0
Leucine	0.9	1.3	1.3	1.3	1.6
Sulfur					
Half cystine	0.0	0.0	0.0	trace	trace
Methionine	0.3	0.4	0.4	0.3	0.4
Aromatic					
Tyrosine	0.4	0.5	0.5	0.4	0.6
Phenylalanine	0.5	0.8	0.9	0.7	0.9
Total Amino Acids	11.1	14.1	14.6	14.3	17.6
Crude protein	19.0	21.4	22.7	23.4	31.0
AA/CP ratio (%)	58.42	65.89	64.32	61.11	56.77
Essential amino acids	5.8	6.7	7.0	6.7	8.1
EAA/CP ratio (%)	30.53	31.31	30.84	28.63	26.13

higher than in the in vitro experiments suggesting additional sources of nitrogen in the natural environment (e.g., adsorbed and/or absorbed soluble nutrients). The essential amino acids, which comprise about 52% of the total amino acids and about 30% of crude protein, also increased from 5.8 mg/g at day 0 to 8.1 mg/g at day 36.

The increases in amino acids and crude protein during in vitro decomposition of fine detrital particles (250 μm) did not parallel in degree the increases we previously observed during in situ decomposition of dead marsh plants to coarse (2.5 mm) particulate detritus. Obviously, the limited conditions inside the incubation flask lack the complex physico-chemical processes occurring on the marsh. For example, fresh-water drainage from land and the regular inundation by saline water during the tidal cycles enrich the marsh substrate and enhance the microbial colonization of decaying organic biomass on the marsh.

Our present observations of amino acids and those of others (Odum and de la Cruz 1967; Heald 1969; de la Cruz and Gabriel 1974) on the nutritive values of decomposing detritus indicate collectively the nutritional enrichment accompanying decomposition. It is believed that this process is brought about by the adsorption and/or absorption of nutrients to the detritus particles, and the growth in the populations of attendant microbiota (e.g., bacteria, fungi, and protozoa). The significance of amino acid-protein enrichment, whether due to microbial colonization or some other physico-chemical agents, lies in the role of detritus as a source of food for estuarine and near-shore marine heterotrophs.

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Gulf Research Reports

Volume 5 | Issue 1

January 1975

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DOI: 10.18785/grr.0501.07

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Recommended Citation

Howse, H. D., J. S. Franks and R. F. Welford. 1975. Pericardial Adhesions in the Cobia *Rachycentron canadum* (Linnaeus). *Gulf Research Reports* 5 (1): 61-62.
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PERICARDIAL ADHESIONS IN THE COBIA *RACHYCENTRON CANADUM* (LINNAEUS)

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ABSTRACT Pericardial adhesions are reported in diseased hearts of the cobia *Rachycentron canadum* (Linnaeus). The epicardium and pericardium are either tightly fused or connected by numerous thick collagenous adhesions over most of the heart surface.

Dockside examination of a sport fisherman's catch of the cobia, *Rachycentron canadum* (Linnaeus), in 1970, revealed three cases of pericardial adhesions. The hearts were removed for further gross and histologic examination. Cardiac tissue was excised, fixed in 10% buffered formalin, and prepared for light microscopy in the usual manner. The following staining methods were carried out on selected tissue sections: hematoxylin and eosin; Masson's trichrome; periodic acid Schiff, after digestion with diastase; Alcian blue (pH 1.0); Alcian blue (pH 2.5) and nuclear fast red; Van Gieson's; and acid orcein.

The pericardium of the normal cobia attaches to the heart only along the anteriodorsal and the dorsolateral edges of the triangular ventricle. This attachment is loose except at the anterolateral angles and the apex. The remainder of the heart is devoid of attachments except for a few scattered and delicate fibrous strands.

The pericardium of hearts with adhesions was tightly bound to most of the heart surface, especially of the atria and along the ventral surface of the ventricle (Figure 1). Histologic preparations showed the pericardium either tightly fused with the epicardium or connected with it by numerous



Figure 1. Ventral view of a normal (left) and a diseased (right) cobia heart. The aortae are directed upward. Note the attachment of the pericardium only at the apex (arrow) of the normal heart. A, atrium; V, ventricle.

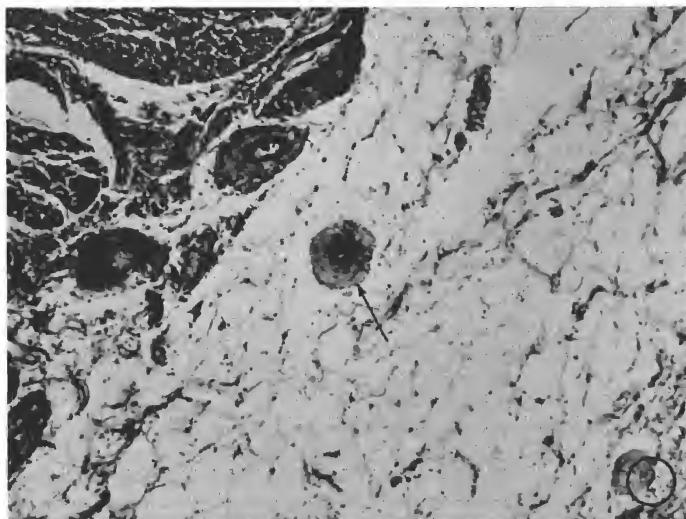


Figure 2. Light micrograph of a cross section through the ventricular myocardium and fused epicardium-pericardium. Note the pacinian corpuscle (arrow) embedded in a collagenous network. $\times 142$.

thick collagenous adhesions (Figure 2). Neither inflammatory cells nor other evidence of inflammatory reactions were present.

Occasionally, pacinian corpuscles were encountered in the fused epicardium-pericardium. Since no pacinian corpuscles were observed in normal epicardium, these end organs were evidently contributed to the fused layer by the pericardium.

Information on inflammatory diseases of fish hearts is essentially non-existent. Bacterial infections are known to cause myocarditis (Wood and Yasutake 1956; Herman 1975) and pericarditis (Herman 1975) in trout. However, pericardial adhesions, usually sequelae to pericarditis in mammals, have

not previously been reported in fish.

One of us (J.S.F.) grossly examined the hearts of numerous cobia at sea in connection with an offshore research project and discovered several additional cases, while another (R.F.W.) encountered a single toadfish, *Opsanus beta*, with pericardial adhesions. Although our findings provided no information concerning the etiology of the pericardial adhesions, they most probably resulted from pericarditis. The disease may occur in a substantial number of cobia of the Gulf of Mexico and a study to determine the incidence of pericardial adhesions in this fish population is planned for the future.

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